



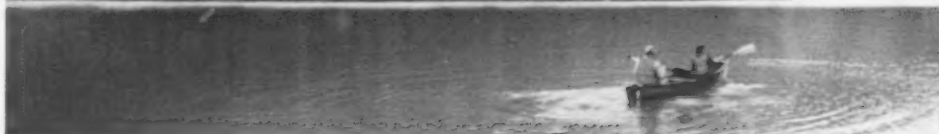
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New Brunswick Shale Gas Air Monitoring Study – Interim Report 01



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New Brunswick Shale Gas Air Monitoring Study – Interim Report 01

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February 21, 2014

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List of abbreviations

AAQO	Ambient Air Quality Objective
AQO	air quality objective
AQS	air quality standard
avg	averaging/average
BAM	Beta Attenuation Mass
BTEX	benzene, toluene, ethylbenzene and xylenes
CAAQS	Canadian Ambient Air Quality Standard
CAC	criteria air contaminant
CALA	Canadian Association for Laboratory Accreditation Inc.
CC	carbonyl compounds
CWS	Canada-wide Standard
DELG	(New Brunswick) Department of Environment and Local Government
EC	elemental carbon
FID	flame ionization detector
GC	gas chromatography
GLP	good laboratory practice
Gravim.	gravimetric particulate matter analysis
HPLC	high-performance liquid chromatography
ICP	inductively coupled plasma
IMPROVE	Interagency Monitoring of Protected Visual Environments
Levogl.	levoglucosan
LPM	litres per minute
max	maximum
MDL	method detection limit
Met.	meteorology
min	minimum
MOA	Memorandum of Agreement for Services
MOU	Memorandum of Understanding
MS	mass spectrometry
MSD	mass selective detector
NAAQO	National Ambient Air Quality Objective
NAPS	National Air Pollution Surveillance
NBAAQO	New Brunswick Ambient Air Quality Objective
NO _x	nitrogen oxides
NPRI	National Pollutant Release Inventory
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PM	particulate matter
PM _{2.5}	particulate matter ≤ 2.5 µm in diameter; fine particulate matter

PM ₁₀	particulate matter $\leq 10 \mu\text{m}$ in diameter
ppb	part per billion
ppm	part per million
PUF	polyurethane foam
QA	quality assurance
QC	quality control
SAS	Statistical Analysis System
SOP	standard operating procedure
SVOC	semi-volatile organic compound
TPM	total particulate matter
TRS	total reduced sulphur
TSP	total suspended particulates
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WHO	World Health Organization

Executive summary

In the fall of 2012, a Memorandum of Agreement for Services (MOA no. 4500290325) between Health Canada and the New Brunswick Department of Environment and Local Government was established to conduct an air monitoring study around shale gas activities in the province of New Brunswick. This first interim report presents the monitoring activities conducted between October 2012 and April 2013 as part of the New Brunswick Shale Gas Air Monitoring Study.

The study consists of four phases that represent as much as possible the different stages of shale gas development: Phase I – baseline conditions prior to any development; Phase II – well development and gas production; Phase III – natural gas processing and distribution; and Phase IV – well closure.

This interim report is limited to data collected at the Phase I site. The analyses in this interim report, mainly through descriptive statistics and time series plots, must be considered preliminary, as the available data set was incomplete. In fact, as of April 2013, data were available mostly for continuous data collected with analyzers that provide real-time results (i.e., carbon monoxide, ozone, sulphur dioxide, total reduced sulphur, fine particulate matter, total suspended particulates and nitrogen oxides). For compounds requiring the collection of physical samples and laboratory analysis (e.g., polycyclic aromatic hydrocarbons, carbonyl compounds), data were limited to a few samples, and no elaborate interpretation was possible.

Preliminary analyses of the data and comparisons with historical air quality trends across the southern part of the province of New Brunswick (including Fredericton, Saint John and Moncton) show that the concentrations of air pollutants at the baseline site were similar to or lower than those at other provincial monitoring sites (rural and/or urban). The wind data also indicated that no significant sources of pollution, especially oil and gas activities, were located upwind of the site. As such, it appears that the baseline data will provide an appropriate data set against which to compare air quality data collected during other phases of the study.

As continuous and discrete data from Phases I, III and IV become available, and once appropriate data quality assurance/data quality control procedures have been conducted, Health Canada will produce a second interim report.

As for Phase II of the current shale gas air monitoring study, covering the well development stage, it will be initiated as soon as a favourable project and site are identified by the New Brunswick Department of Environment and Local Government.

1. Background and scope

During the fall of 2012, a Memorandum of Agreement for Services (MOA no. 4500290325) between Health Canada and the New Brunswick Department of Environment and Local Government (DELG) was established to conduct an air monitoring study around shale gas activities in the province of New Brunswick. This first interim report aims to present information regarding monitoring activities and results from the first months of the New Brunswick Shale Gas Air Monitoring Study.

The report presents data collected at the baseline or Phase I site from October 2012 to April 2013, through descriptive statistics and time series plots. The analyses in this interim report must be considered preliminary, as the available data set is incomplete (i.e., approximately 6 months of activity). Further, data are available mostly for continuous data collected with analyzers that provide real-time results (i.e., carbon monoxide (CO), ozone (O₃), sulphur dioxide (SO₂), total reduced sulphur (TRS), fine particulate matter (PM_{2.5}), total suspended particulates (TSP) and nitrogen oxides (NO_x)). For other compounds, such as volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs), physical samples were collected (e.g., filters, canisters), which require laboratory analysis. A delay of several weeks is expected between submitting samples to the laboratory and obtaining the results. As such, data are limited to a few samples, and no definitive interpretation will be made until all laboratory analysis data are available.

The structure of the report is as follows: Chapter 2 provides an overview of the study phases and the data collection approach; Chapter 3 presents the monitoring approach and methodologies; and Chapter 4 provides a preliminary analysis of the data, including, when available and relevant, a comparison with historical data from provincial air monitoring stations located across the southern portion of the province of New Brunswick. A status report on activities initiated and/or planned for the other phases of the study is included in Chapter 5, and Chapter 6 provides concluding remarks.

Appendices A and B present the data in tables and time series plots, respectively. Appendix C provides relevant meteorological data. Appendix D includes supplementary information on air monitoring equipment and laboratory analyses, and Appendix E summarizes air quality data from the New Brunswick provincial monitoring network. Appendix F outlines the data quality assurance (QA) and data quality control (QC) procedures adopted for the current study. Finally, Appendix G presents the air quality objectives in New Brunswick and Canada, which provide some perspective for the data analysis.

2. Overview of study objectives, study phases and data collection approach

2.1 Study objectives and location

The New Brunswick Shale Gas Air Monitoring Study is a joint project between Health Canada and the New Brunswick DELG, with the additional participation of Environment Canada. The overall objective of this project is to assess risks to public health from air emissions associated with shale

gas development and operations. Before such an evaluation is possible, it is necessary to identify and characterize ambient concentrations of criteria air pollutants and air toxics at a representative background location. The same air quality measurements will then be taken near unconventional natural gas production, treatment and distribution infrastructures and operations.¹ A comparison of the monitoring results will identify which chemical compounds increase in concentration in the air near such infrastructures and operations and allow for an assessment of potential health impacts and concerns. It is noted that the purpose of this study is not to determine pollutant concentrations associated with other unconventional natural gas production locations across New Brunswick or Canada, as the scope of the study design is geographically limited. Additional data analysis and potentially air monitoring would support extrapolating the results from this study to other shale gas plays. Nonetheless, the study has the potential to indicate possible air quality issues that could be transferable to other jurisdictions.

Air quality monitoring is being conducted in the general area of Sussex in Kings County, New Brunswick. All sampling locations are situated within the Kennebecasis River valley, with southeasterly dominant winds in the summer and northeasterly or northwesterly dominant winds during the winter. Figure 1 shows the general area and the road network around Sussex. This area is mainly agricultural (dairy farms), with natural gas production and treatment (Corridor Resources Inc.²) and potash mining and processing (PotashCorp³) also being economically active in the region.



Figure 1. General area of the shale gas study near Sussex, New Brunswick

¹ The term unconventional refers to natural gas resources that require the utilisation of specific stimulation methods, such as horizontal drilling and hydraulic fracturing, for their commercial production.

² www.corridor.ca/index.html

³ www.potashcorp.com/about/facilities/potash/new_brunswick/

(Source: Image generated with Google Earth)

Selection of this area for the air monitoring study was based on industry's activities and interest in oil and gas resources in the McCully field. The McCully field is roughly centred on Penobsquis, located approximately 10 km northeast of Sussex. Figure 2 shows the oil and gas leases in the Sussex area. Corridor Resources Inc. is currently the most active gas producer and lease holder in the area.

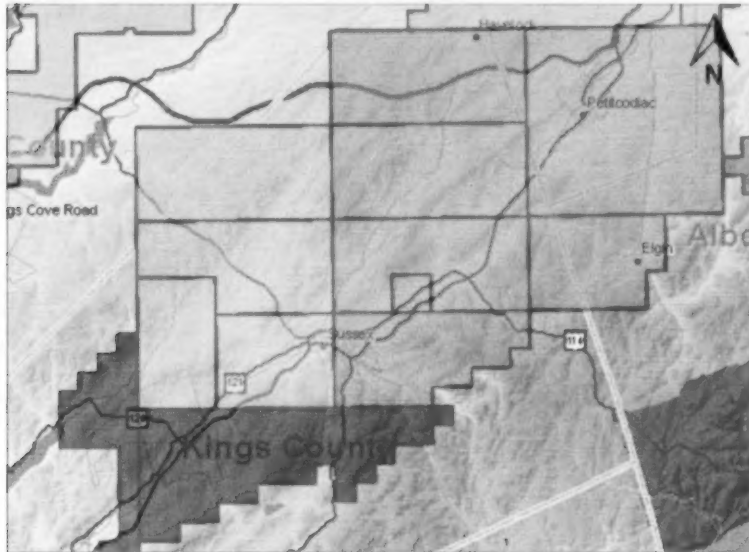


Figure 2. Oil and gas leases in the area of Sussex, New Brunswick

Legend: Yellow: PotashCorp; Green: Corridor Resources Inc.; Dark grey: Corridor Resources Inc./PotashCorp; Light grey: Corridor Resources Inc./Windsor Energy Inc.; Blue: Windsor Energy Inc.; Beige: Beneficial Energy Group, LLC (as of August 2013; www.snb.ca/geonb1/e/index-E.asp)

Several conventional natural gas wells have been drilled in this formation and are producing gas. Several unconventional natural gas wells have also been drilled and completed. Figure 3 shows the location and distribution of oil and gas wells near Penobsquis. Additional wells, both conventional and unconventional, may be drilled, completed and/or put into production if the existing pipeline infrastructure is expanded and/or if the market supports natural gas development.

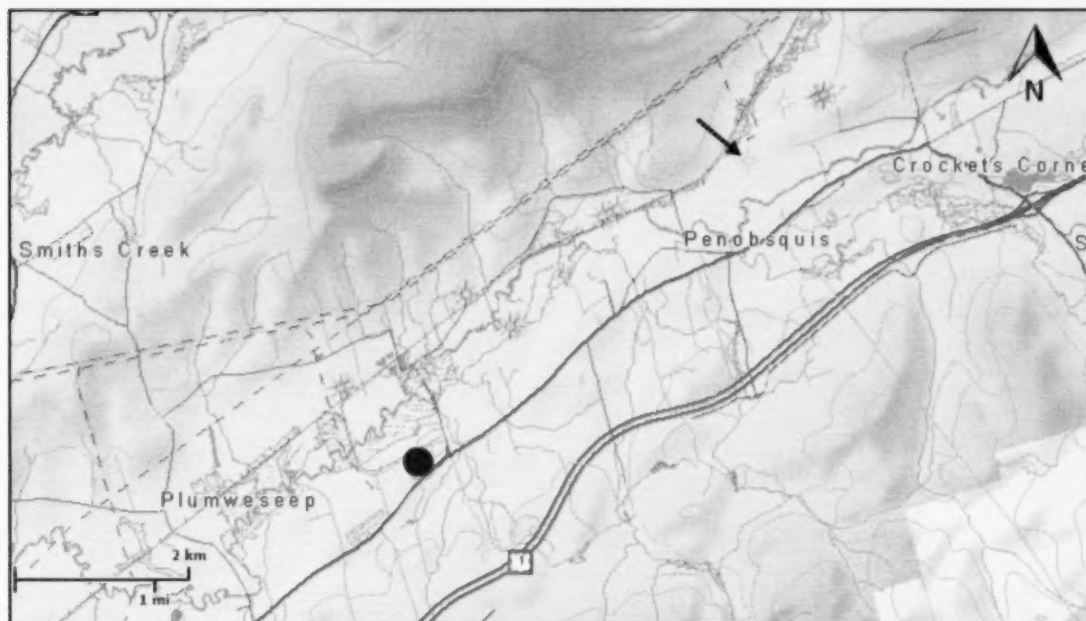


Figure 3. Oil and gas wells near Penobsquis, New Brunswick

Notes: Due to the large scale of the map, some symbols overlap, and thus each symbol may represent more than one well. The arrow indicates the location of the gas plant operated by Corridor Resources Inc. in Penobsquis. The dark circle indicates the location of the PotashCorp facility, where a second gas plant is operational (Source: www.snb.ca/geonb1/e/index-E.asp)

2.2 Study phases

The study consists of four phases that represent as much as possible the different stages of unconventional natural gas development:

- Phase I: baseline conditions prior to any development;
- Phase II: well development and gas production;
- Phase III: natural gas processing and distribution; and
- Phase IV: well closure.

In order to characterize air pollutant levels associated with the different stages of unconventional natural gas production using hydraulic fracturing, it was necessary to investigate the defined stages at different locations across the Sussex region. It was not feasible to monitor air pollutant levels during all phases at a single site, since predicting the exact location of future wells is highly uncertain and because wells may produce gas for more than 20 years. All sites will be located within the same geographic area (i.e., Kennebecasis River valley; see Figure 1). As such, it is expected that air monitoring will be representative of the life cycle stages of an individual well or installation in the area.

It must be noted that the study phases, although sequentially numbered, do not imply a specific order for initiating and completing the monitoring work. They merely reflect a schematic of natural

gas development from an undeveloped site to gas production, gas transport and, finally, well closure. More details regarding phases of the study are provided in Chapters 3 and 5.

2.2.1 Phase I: Baseline conditions prior to any development

The baseline site is in Apohaqui, located southwest of Sussex within the Kennebecasis River valley (see Figure 1). This site was selected because it is located near an area of interest where shale gas development and associated air quality impacts may occur in the future. It is also suitable as a baseline site because it is not currently being impacted by shale gas development. This site is located upwind of the other designated sampling sites (i.e., Phase III and Phase IV) and also upwind of Penobsquis, where multiple natural gas wells and two gas plants are currently in operation (see Figure 3).

The selection of the site was based on local knowledge, DELG expertise and industry interest (reflected by oil and natural gas licences and leases; see Figure 2).⁴ The mobile monitoring unit (see Photo 1) was deployed at this location, and data collection commenced, in October 2012. Data collection ended in October 2013. A full year of data will improve the likelihood of identifying any seasonal variations in background air quality. The site and its surroundings can be described as being mostly agricultural in nature, with a few scattered woodlots and small hills (see Photo 1). No industrial facility is located near the site, and the population density is very low. No physical obstructions are located within several hundred metres of the monitoring station.



Photo 1. Mobile monitoring unit at the baseline site in Apohaqui, New Brunswick

⁴ www.gnb.ca/0078/minerals/ONG_Data-e.aspx#RightsMaps

2.2.2 Phase II: Well development and gas production

It is expected that air quality monitoring will be conducted at a shale gas production site over the course of a year and will cover the period in which a new well is being developed – that is, during well pad construction, drilling, hydraulic fracturing (or fracking) and well completion – up to gas production. The site will be identified and selected by DELG as part of New Brunswick's environmental impact assessment process for oil and gas activities. Initiation of this phase is entirely dependent on industry activity.

2.2.3 Phase III: Natural gas processing and distribution

A gas plant owned and operated by Corridor Resources Inc. is located on Route 114 in Penobsquis (Figures 2 and 3; Photo 2). Natural gas from regional wells is collected and treated at this facility, before market distribution via pipeline. The gas plant is connected to the Maritimes and Northeast Pipeline. The natural gas processed at this site originates from both conventional and unconventional wells in the McCully field. Although the focus of this study is on shale gas, which is a form of unconventional natural gas, the gas plant operated by Corridor Resources Inc. is considered representative of any gas plant that would process natural gas. In fact, when the natural gas reaches the gas plant for treatment and distribution, the type of resource (i.e., conventional or unconventional) and extraction method (i.e., with or without hydraulic fracturing) should not have an impact on emissions from the facility.



Photo 2. General view of the Corridor Resources Inc. gas plant in Penobsquis, New Brunswick

Air monitoring during Phase III of this study will allow for an assessment of the potential impacts from increased shale gas production in the region arising from the operation of additional gas plants. Data collection at this site was conducted over a 12-week period between June 7 and August 27, 2013, with a more intensive sampling program during the first 6 weeks. The land directly surrounding the gas plant is mainly agricultural or forested (see Figure 5 in Section 3.3 below). The monitoring period was selected to be in between major agricultural operations, such as manure

spreading and harvesting, in order to avoid unnecessary confounding of the results due to these operations (e.g., excessive particulate matter emissions).

This facility, because of its limited emissions, is currently not required to report emissions to the National Pollutant Release Inventory (NPRI), and, as such, emissions data were not publicly available. In the same area, only three facilities reported emissions to the NPRI (Table 1). None of the facilities listed on the NPRI is directly involved in oil and gas operations. Particulate matter (PM) and VOCs are the most significant air emissions reported. Although it is not included on the NPRI registry, there is also a quarry (gravel, sand) located within 2 km south of the gas plant. This facility is expected to be a significant source of PM, likely in the coarse range (i.e., particles larger than 2.5 μm).

A gas plant is operational at the PotashCorp facility (joint venture with Corridor Resources Inc.) to provide power to equipment on site. The emissions from this gas plant are aggregated with the other releases from the PotashCorp facility reported to the NPRI and cannot be isolated. Further, several gas wells are producing in the area. Emissions from individual gas wells and other gas facilities (gas plants or compressors) are likely below the required reporting thresholds; hence, there are no NPRI data for these activities.

Table 1. Facility and substance information near the Phase III site, based on NPRI data for 2012

	Amount of substance (tonnes)		
	PotashCorp ^a	Newalta Corporation ^b	J.D. Irving Ltd. Sussex Sawmill ^c
Air emissions			
TPM	111		390
PM ₁₀	76		238
PM _{2.5}	45		7.0
CO	27		
NO _x (as NO ₂)	38		
VOCs	130		
Off-site disposal			
Methanol		26	
Toluene		97	
Xylenes		26	
Methyl ethyl ketone		26	
Off-site recycling			
Methanol	24		
Abbreviations: PM _{2.5} , particulate matter $\leq 2.5 \mu\text{m}$ in diameter; PM ₁₀ , particulate matter $\leq 10 \mu\text{m}$ in diameter; TPM, total particulate matter; VOCs, volatile organic compounds			
^a 9 McCully Station Road, Penobscis, NB E4G 2B4 (5 km southwest from Phase III site).			
^b 17 Jones Court, Sussex, NB E4E 2S2 (10.5 km southwest from Phase III site).			
^c 39c route 890, Sussex, NB E4G 2W1 (11.5 km southwest from Phase III site).			
Source: ec.gc.ca/inrp-npri/donnees-data/index.cfm?do=query&lang=en			

2.2.4 Phase IV: Well closure

Phase IV of the study aims to characterize potential emissions from a decommissioned well (i.e., after the active or operational life of the well has ceased). At the end of a well's economically useful life, it is usually decommissioned – that is, the well head is removed, the well is capped with concrete and the land is reclaimed. As the use of fracking for natural gas production in New Brunswick is relatively new, it was not possible to identify a natural gas well that had experienced horizontal fracking, was put into production and was decommissioned. Instead, the best alternative was a site where fracking has occurred in two wells, one horizontal (B-41; water used as fracking fluid) and one vertical (G-41; liquid propane used as fracking fluid).

The well heads are still present (see Photo 3), but the wells are inactive – that is, natural gas is not currently being produced at this site for technical and/or economic reasons. However, the G-41 well is believed to be economically viable and could potentially be producing in the future with the expansion of the regional pipeline system.

The Phase IV site, also referred to as the Green Road site, is located north of Elgin, New Brunswick, and is owned by Corridor Resources Inc. The surrounding area is mainly forested. Data at this site were collected over a 6-week period between April 23 and June 6, 2013.



Photo 3. Inactive well heads at the Corridor Resources Inc. Green Road site near Elgin, New Brunswick

(Note: Large vertical steel tanks are located on site and visible in the right-hand part of the photograph. These tanks were empty during our site visits.)

3. Data collection – monitoring activities and methodologies

As part of the New Brunswick Shale Gas Air Monitoring Study, data are being collected by the DELG and Health Canada. Their responsibilities are essentially as follows:

- The DELG is collecting data using the mobile monitoring unit provided by Environment Canada through the National Air Pollution Surveillance (NAPS) program Memorandum of Understanding (MOU) between provinces, territories and the federal government.
- The DELG also acquired new equipment and samplers for the monitoring of methane.
- The DELG is responsible for the majority of the fieldwork, including routine site visits, equipment maintenance, discrete sampling, shipping and handling of samples, and proper recording of activities (log sheets and log books).
- Health Canada is providing additional monitoring equipment and support, as outlined in the MOA between Health Canada and the DELG.
- Health Canada provides technical support through regular communications and necessary site visits.
- Health Canada and the DELG are responsible for validating the data collected with their respective monitoring and sampling equipment, as per recognized QA/QC procedures (see Appendix F).
- Health Canada and the DELG are sharing the data collected during various phases of this study, on an equitable, timely and mutually beneficial basis. The data collected during this study are considered “public,” as required under the NAPS MOU and as stipulated in the MOA.

Details regarding specific monitoring activities during the different phases are provided in the following sections.

3.1 Baseline site: Phase I

Data collected during Phase I are either continuous (e.g., every 5 minutes) or discrete (e.g., filter- or canister-based samples). Continuous data are recorded and stored in data loggers connected to the monitoring units. These data are directly available and can be accessed, for example, via wireless connections or downloaded when a technician visits the site. Discrete samples require that a technician physically install the sampling units and collect the samples according to protocol. The samples are then sent to designated laboratories for analysis. Table 2 shows the air quality and environmental parameters monitored at the baseline site.

As a result of normal delays for chemical analysis and data validation, the analytical results for discrete samples are not immediately available. Subsequently, whereas continuous data from October 1, 2012, to April 16, 2013, are included in this interim report, discrete data are not available for all samples collected up to April 16, 2013.

Table D1 in Appendix D shows the monitoring equipment used to measure parameters at the Phase I site. Most instruments were active on October 1, 2012. The analyzer for TSP was activated on November 1, 2012. Although not specific to the monitoring site, additional environmental data, such

as temperature and precipitation, are available from the Meteorological Service of Canada at Environment Canada for several locations across New Brunswick.

Sampling for methane was initiated in June 2013. Air bag samples were collected weekly on top of the mobile unit using the lung sampling method.⁵ Sample analysis for methane and ethane was conducted by RPC laboratories, located in Fredericton, New Brunswick. A continuous methane monitor was also tested during part of Phase I. Continuous and discrete data for methane and ethane will be discussed in subsequent reports.

Table 2. Continuous and discrete environmental and air quality parameters monitored during Phase I

Data type	Parameter and sampling frequency	
	Continuous	Discrete
Environmental	Wind speed and direction Relative humidity Temperature Barometric pressure	
Air quality	Sulphur dioxide (SO ₂) Total reduced sulphur (TRS) Carbon monoxide (CO) Nitrogen oxides (NO ₂ /NO _x) Particulate matter (PM) - Total suspended particulates (TSP) - Fine PM (PM _{2.5}) Ozone (O ₃)	PM _{2.5} - Gravimetric, filter-based - PM metals analysis - PM chemical speciation (levoglucosan compounds; elemental and organic carbon) Volatile organic compounds (VOCs) - Canisters; 24-hour sampling; 1 in 6 days - Passive VOC samplers; 7-day sampling Semi-VOCs (SVOCs) ^a - Filter based; every 12 days Carbonyl compounds ^b - Canisters; 24-hour sampling; 1 in 6 days
^a Includes dioxins, furans and PAHs.		
^b Examples: acetaldehyde and hexanal.		

VOC samples were actively collected using clean evacuated 6 L Summa™ canisters. These Summa canisters were equipped with precalibrated flow controllers that operate at a flow rate of 3.5 ml/min. Automatic timers allowed technicians to collect 24-hour samples on specific days of the week. The air samples were analyzed for a suite of VOCs using gas chromatography–mass spectrometry (GC/MS), according to United States Environmental Protection Agency (US EPA) method TO-15, at Environment Canada laboratories.

Passive VOC samples were collected with 3M Model 3500 Organic Vapour Passive Samplers (OVM; Guillevan, Montréal), which were analyzed by Airzone One (AirZOne, Mississauga, ON) using gas chromatography with a mass selective detector (GC/MSD). OVM badges were exposed to ambient air for 7 days (target duration). In Appendix D, Tables D2 and D3 list the VOC species for which

⁵ Refer to www.caslab.com/Forms-Downloads/Flyers/Lung_Sampler_Instructions.pdf

analysis was carried out for the active (canister) and passive (OVM badge) samples, respectively.⁶ Additional information about the analytical procedures used can be found in Miller et al. (2012) and Wheeler et al. (2008).

Air samples were collected on a solid adsorbent (2,4-dinitrophenylhydrazine) for the analysis of carbonyl compounds. Carbonyl compound samples were collected from the mobile monitoring unit using a Xonteck Model 926 Carbonyl Sampler. These samples were analyzed by Environment Canada using high-performance liquid chromatography (HPLC).

PAH samples were collected using the URG Personal Pesticide sampler, within which PM_{2.5}-bound PAHs were collected on a glass fibre filter and gaseous PAHs were collected on a 5 cm plug of polyurethane foam (PUF). Samples were sent to AirZOne laboratories for analysis (measured PAHs are listed in Table D4 in Appendix D).

PAH samples were also collected over a 24-hour period using a modified high-volume sampler equipped with a Roots meter (model 8C175-CTR-NPDL-MTC-SA). Air was drawn through a Teflon-coated glass fibre filter that was followed by a PUF plug, allowing for the collection of both gaseous and PM_{2.5}-bound PAHs. Samples were analyzed by Environment Canada (Method No. 3.03/5.1/M).

Fine particulate matter (PM_{2.5}) 24-hour integrated samples were collected during Phase I using ChemComb Speciation Cartridges (Model 3500, ThermoScientific, Waltham, MA, USA). The ChemComb cartridges were operated at a flow rate of 10 LPM using a Partisol 2300 (ThermoScientific). Samples were sent to Alberta Innovates for gravimetric and inductively coupled plasma mass spectrometric (ICP-MS) metals analysis (metals analyzed are listed in Table D5 in Appendix D). Gravimetric analyses were conducted using the method outlined in the US EPA Quality Assurance Guidance Document 2.12 (US EPA 1998).

Elemental carbon and organic carbon (EC/OC) and levoglucosan were collected using a ChemComb Speciation Cartridge (Model 3500, ThermoScientific, Waltham, MA, USA) operated at a flow rate of 10 LPM with a PM_{2.5} inlet using a Partisol 2300 (ThermoScientific). A pre-fired quartz fibre filter inside the ChemComb sampler was used to collect 24-hour integrated samples. After exposure, the sampled filter was analyzed by Environment Canada for carbon content using a DRI Model 2001 thermal/dual-optical carbon analyzer (Atmoslytic Inc., Calabasas, CA, USA) and the Interagency Monitoring of Protected Visual Environments (IMPROVE) analysis protocol. Environment Canada also conducted ion chromatography analysis of 47 mm Teflon filters for levoglucosan.

3.2 Inactive well site: Phase IV

Monitoring at the Phase IV site was initiated on April 23, 2013, and ended on June 6, 2013. Fugitive emissions from the well heads and adjacent areas were the focus for the monitoring at this site. As there are no sources of combustion emissions on site, emissions of pollutants such as PM, NO_x and

⁶ The sampling and analytical methods presented could vary if, when the information regarding the composition of the fracking fluid or on-site equipment and procedures becomes available, there is sufficient evidence to indicate that modifications are required to capture pollutants of concern.

CO, for example, were not expected. Hence, only VOCs (including carbonyl compounds and methane) were monitored, using passive 3M OVM VOC badges, Summa canisters and air bag samples. Monitoring was conducted for only 6 weeks, as no seasonal variations in air quality associated with emissions from the well heads are expected at this site.

OVM badges were exposed for 6–7 days and then replaced. They represent an integrated sample over approximately 1 week. Field blanks were collected each week. The Summa canisters were activated by timers and collected a 24-hour integrated sample. It was originally planned to collect samples once every 6 days. However, the sampling schedule was modified due to technical problems. This will be discussed in a subsequent report.

Figure 4 shows the general layout of the sampling site for Phase IV. Note that there are actually two well heads at the 41 location, G-41 and B-41 (see Photo 3 in Section 2.2.4). Passive OVM badges were deployed at all locations (41–45), and Summa canisters were deployed at locations 41 (well heads) and 43 (expected downwind based on prevailing winds). The area covered by the sampling locations corresponds to the surface cleared during the well development stage of the existing wells. In relation to the well heads (i.e., location 41), locations 42, 43, 44 and 45 are approximately 50, 74, 71 and 55 m away, respectively.

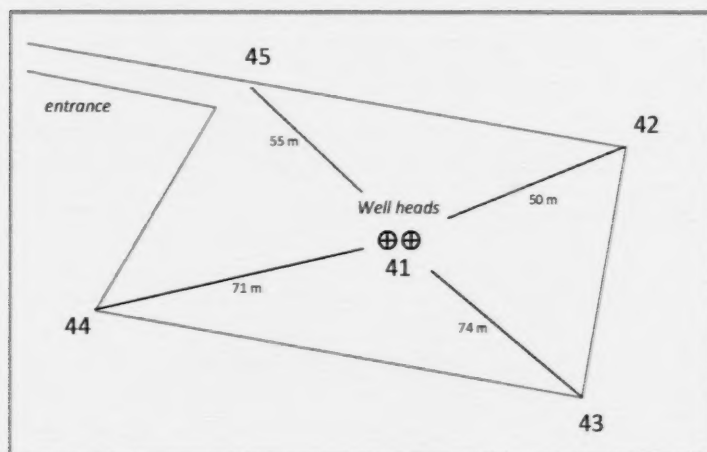


Figure 4. Schematic of monitoring locations at the Phase IV sampling site (not to scale)

Sampling for methane was also conducted weekly and/or when personnel were on site performing other tasks. Air bag samples were collected directly beside the well heads using the lung sampling method. The technician positioned the sampler downwind of the well heads (the exact location changed according to wind conditions during the visit). Analysis of samples was conducted by RPC laboratories, located in Fredericton, New Brunswick.

3.3 Gas plant: Phase III

Monitoring at the Phase III site was conducted between June 7 and August 27, 2013. The monitoring approach for the Corridor Resources Inc. gas plant site utilized an inner and an outer ring, each with

four sampling locations. Figures 5 and 6 show the general layout for the Phase III site. Sites 31, 32, 33 and 34 were located on the fence line (i.e., passive monitors were attached to the fence itself) of the gas plant. Sites 35, 36, 37 and 38 were located approximately 300, 565, 470 and 280 m, respectively, from the nearest point of the facility fence line.

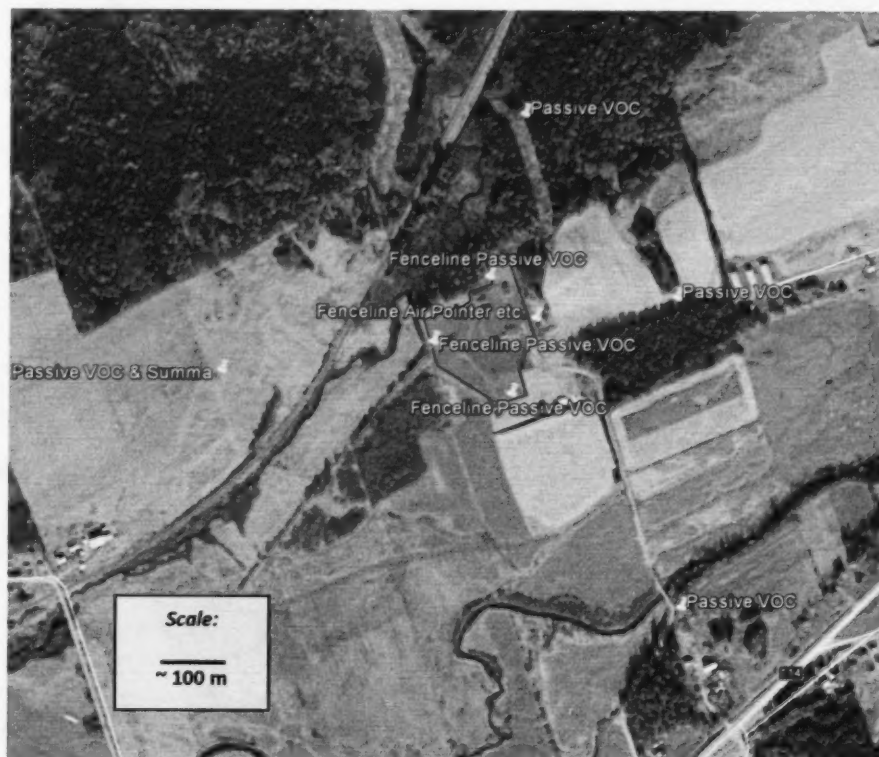


Figure 5. Aerial schematic of sampling locations at the Phase III site (Source: Darrell Welles, DELG, and Google Earth) *Legend:* The area outlined in blue is the gas plant fence line perimeter; sampling locations are identified by the yellow pins.

A 4D Airpointer ambient air quality monitoring system was deployed at location 31. This unit provided 1-hour concentrations of NO_x , SO_2 , TRS, O_3 and $\text{PM}_{2.5}$ based on 1-minute measurements. Meteorology was also measured using the Airpointer. The Airpointer was calibrated on site according to standard procedures prior to the start of data collection. For the first 6 weeks of monitoring, $\text{PM}_{2.5}$ 24-hour integrated samples were also collected at location 31 using ChemComb Speciation Cartridges (ThermoScientific, Waltham, MA, USA) with a BGI pump (10 LPM Model 40010s, BGI Inc., Waltham, MA, USA). Samples were sent to Alberta Innovates for gravimetric analysis. In addition, at location 31, PAH samples were collected using the URG Personal Pesticide sampler, similar to the method outlined in Phase I, and sampling was conducted for methane using the lung sampling method.

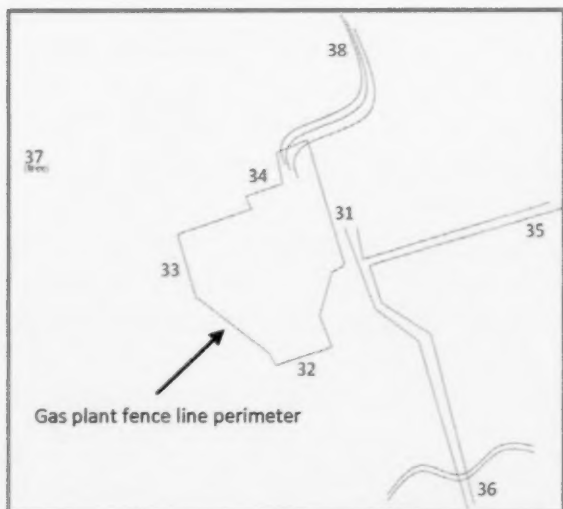


Figure 6. Schematic of sampling locations at the Phase III site (not to scale)

Also during the first 6 weeks of monitoring, passive OVM badges were deployed at all eight locations, and Summa canisters were installed at locations 31 and 37, identified in Figure 6.

Following the first 6 weeks of monitoring, it was agreed with Corridor Resources Inc. to extend the continuous monitoring with the Airpointer unit (i.e., NO_x , SO_2 , TRS, O_3 and $\text{PM}_{2.5}$) at location 31 for an additional 6 weeks. The Airpointer's continuous CO module was operational during this second half of Phase III monitoring.⁷ As no significant seasonal variations in operations are projected for the facility, the 12-week monitoring period was considered sufficient to adequately categorize the air quality around the gas plant facility.

4. Data analysis – Phase I

Data included in the current analysis encompass continuous data and discrete data collected between October 1, 2012, and April 16, 2013.⁸ However, discrete data are limited to samples for which analytical results were available by April 30, 2013.

Table A1 in Appendix A summarizes the descriptive statistics for the available continuous data. The period covered in this interim report includes 198 sampling days. The number of measurements differs substantially between PM (fine and total) (i.e., 4728 measurements) and other pollutants (i.e., 56 736 measurements). For SO_2 , TRS, NO_2 , NO, CO and O_3 , the basic measurement unit was 5 minutes (i.e., data were collected every 5 minutes), whereas PM data were collected hourly; as a result, the number of measurements differ by a factor of 12.

⁷ The CO module was found to be dysfunctional during the initial set-up and calibration of the Airpointer on June 6, 2013. A new CO module was installed at the start of the second 6-week segment.

⁸ Corresponds to data collection activities reported up to biweekly report 012. Biweekly reports are internal documents submitted by the DELG to Health Canada (NB DELG 2012–2013).

The row *No. of valid measurements* shows the number of measurements in the data set that were considered to be of acceptable quality. From a data validation perspective, at least 75% of the data set must be valid. This requirement was met for all pollutants except TSP, because of an equipment malfunction.

For the mean, median, minimum, maximum and percentile values shown in Table A1, the descriptive statistics were calculated from the air quality standard (AQS) average period (*Avg period for stats* row) to allow for a relevant comparison with the reference AQS (*Air quality standard (AQS)* row). For example, 1-hour averages were determined for CO based on the valid 5-minute data (75% of the hourly data must be valid for the 1-hour average to be considered valid), and the mean of the 1-hour averages is shown in the *Mean* row (75% of the 1-hour averages must be valid for the statistic to be valid).

For PM, the same approach was used; in this case, however, the 1-hour data were averaged on a daily basis (75% of 1-hour data required to be valid). The daily average values were then used to calculate the statistics in Table A1 for PM_{2.5} and TSP.

For O₃, the 5-minute data were initially converted to hourly averages. Afterwards, the hourly data were used to generate 8-hour rolling averages, and the daily maximum value was retained. The 8-hour daily maximum value was subsequently used to calculate the statistics for O₃. The 75% completeness criterion applies to the 5-minute data and the hourly data. No fewer than six hourly values per each rolling 8-hour segment must be valid. Concentrations of O₃ are reported as daily maximum 8-hour running averages for comparison with the Canada-wide Standard (CWS) of 65 parts per billion (ppb).

Also included in Table A1 are the relevant Canadian (federal, provincial or territorial) or international (e.g., World Health Organization (WHO)) air quality objectives for comparative purposes (*Reference* row). Appendix G includes a detailed discussion of air quality standards applicable in New Brunswick and that are relevant for the current interim report.

Tables A2–A5 in Appendix A present discrete (i.e., non-continuous) data available as of April 30, 2013. These data originate from passive and active sampling (e.g., badges, filters or canisters) conducted at the Phase I site. Not all data are available due to normal delays associated with laboratory analysis of the samples.⁹

In Appendix B, Figures B1–B6 present time series plots for O₃, PM_{2.5}, CO, SO₂, TRS and NO₂. The plots for O₃ and PM_{2.5} include a line representing a reference air quality standard, the national 1-hour average 82 ppb for O₃ and the WHO daily average 25 µg/m³ for PM_{2.5}, respectively. For situations in which the reference values were significantly higher than the values from the on-site measurements, the reference values were not displayed on the plots. For example, a maximum

⁹ Only Health Canada samples are included. Sample collection was initiated on November 23, 2012, for PM speciation and PAHs and on November 22, 2012, for passive VOCs. Results for DELG samples, which were collected as of October 10, 2012, will be presented in subsequent reports.

value of 14 ppb NO₂ was recorded during Phase I, compared with a provincial air quality standard of 210 ppb.

Data collected at the baseline site were compared with data from nearby provincial monitoring sites. Section G2 in Appendix G describes the air monitoring network in New Brunswick. For O₃, data were available from two rural sites, Norton and Fundy National Park. For pollutants other than O₃, comparisons were made with monitoring sites located in urban areas, including Moncton, Fredericton and Saint John. Although the Phase I site is not an urban site, these urban sites were selected for comparison because they included the most complete set of pollutants. Further, they are located in the southern part of the province, within 150 km of the Phase I site, and are likely impacted by similar regional air quality and weather patterns. These data were taken from *New Brunswick air quality monitoring results 2010* (New Brunswick DELG 2012). Air monitoring data for the year 2010 are summarized in Appendix E, in addition to historical annual trends for select pollutants.

The following sections provide information regarding the measured criteria air contaminants (CACs) (i.e., O₃, PM_{2.5}, CO, SO₂, VOCs and NO₂) and other measured pollutants or parameters (i.e., TRS, PAHs and meteorological data). Section 4.9 covers data collection issues encountered during the monitoring period. It must be considered that even in remote locations, pollutants such as particulates and VOCs will be detected in background ambient air samples. The presence and detection of air pollutants in ambient air are not a definitive indication of an impact from specific activities.

4.1 Ozone

Based on hourly mean data, mean and median values of 29.3 and 31.3 ppb, respectively, were obtained. A maximum of 56.9 ppb was also observed, which is below the 1-hour national air quality objective of 82 ppb (i.e., no exceedance reported). Refer to Table A1 in Appendix A for more descriptive statistics. Figure B1 in Appendix B shows 1-hour average data in comparison with the National Ambient Air Quality Objective (NAAQO) of 82 ppb.

The O₃ levels during Phase I are lower than but comparable to the levels recorded from January to April 2010 at the Norton site and from October to December 2010 at the Fundy National Park site, which appear to average around 35–40 ppb, based on Figure E4 in Appendix E. Analysis of NAPS data from the Norton station between 2005 and 2010 show mean annual O₃ concentrations of 26.6, 25.6, 25.8, 26.4, 24.5 and 26.0 ppb, respectively, for an overall mean of 25.8 ppb during that period.

Similarly, across all air monitoring sites in the province of New Brunswick, O₃ concentrations averaged around 26 ppb, based on data from 2002 to 2010 (see Figure E5 in Appendix E). This is also comparable to the mean value obtained during the first months of monitoring at Phase I. The O₃ levels in the southern part of the province are highly impacted by long-range or transboundary transport of pollutants from the northeastern United States, Quebec and Ontario. This likely explains the relatively elevated O₃ levels at the Phase I, Norton and Fundy sites compared with the

provincial average levels (Environment Canada 2006). Further, NAPS O₃ data from previous years show that winter O₃ levels are generally higher than summertime levels by as much as 20 ppb.

Based on the maximum daily 8-hour rolling average for O₃, a mean of 36.2 ppb and a median of 36.8 ppb were recorded at the Phase I site for the period covered in this interim report.

4.2 Fine particulate matter

4.2.1 Continuous measurements

Fine PM levels are reported as daily 24-hour averages. Figure B2 in Appendix B shows a time series plot of PM_{2.5} levels measured between October 2012 and April 2013. The average concentration over the first 6 months of monitoring is 4.7 µg/m³, lower than the 7.3 µg/m³ annual average reported in 2010 at the Forest Hills site near Saint John, but similar to levels observed in Fredericton and Moncton.

One exceedance of the WHO PM_{2.5} limit of 25 µg/m³ was reported on February 9, 2013, at the Phase I site (35.5 µg/m³). This exceedance is somewhat unusual, as winter PM_{2.5} concentrations in rural areas of New Brunswick rarely reach such high levels. Upon investigation, it was observed that high PM_{2.5} concentrations were recorded over several hours. Further, they were observed at several monitoring locations in southern New Brunswick, and no other measured pollutant showed any noticeable variation during the same period. Analysis of the meteorological data for February 9 shows that recorded wind speeds at the Phase I site averaged nearly 40 km/h. Meteorological data from Environment Canada for Moncton and Saint John show average wind speeds between 50 and 60 km/h for most of that day.¹⁰ Gusts up to 160 km/h were even reported in Nova Scotia.¹¹ The severe winds and snowfall corresponded with a major winter storm that hit the whole northeastern United States and eastern Canada between February 8 and 10, 2013. Although the exact cause of this rise in PM_{2.5} level has not been determined, it is suggested that the violent winds may have impacted the Beta Attenuation Mass (BAM) monitors that are part of the provincial air monitoring network, in addition to the BAM unit at the Phase I site. A BAM monitor accurately determines PM_{2.5} concentrations by measuring the difference in beta ray transmission of a filter area prior to and following exposure in the inlet port of the unit. By considerably shaking the inlet ports, the unusually strong winds may have dislodged some of the accumulated dust within them. The accumulation of dust in the inlet ports is not unusual and under normal conditions does not impact the measurements. Therefore, the PM_{2.5} measurements collected with the BAM unit at the Phase I site are currently under review and may be removed from subsequent analyses.

4.2.2 Discrete samples

Tables A2 and A3 in Appendix A show gravimetric PM_{2.5} data for 47 mm Teflon filters collected at the Phase I site. These samples were collected using ChemComb Speciation Cartridges. Although collected using the same method, the data are shown in two separate tables, as the filters were

¹⁰ climate.weather.gc.ca/index_e.html

¹¹ en.wikipedia.org/wiki/February_2013_nor'easter

destined for two distinct purposes, one for the analysis of levoglucosan compounds and the other for the analysis of metals.

The median and mean PM_{2.5} concentrations in Table A2 are 4.6 and 4.4 µg/m³, respectively, and in Table A3, 3.2 and 3.7 µg/m³, respectively. Although the samples were collected at the same location, the PM_{2.5} gravimetric data appear to differ. It is important to note that these descriptive statistics are based on samples collected over different time periods. In fact, Table A2 includes 19 samples, whereas Table A3 includes only 8 samples. Thus, a more appropriate evaluation will be possible when all analyses of all samples are available.

4.3 Carbon monoxide

CO concentrations at the Phase I site were below 1 ppm (see Figure B3 in Appendix B) during the period covered, with a mean and a median both around 0.21 ppm, and appear to be comparable to concentrations recorded in larger urban centres of New-Brunswick. A maximum CO concentration of 0.74 ppm was recorded on December 1, 2012, at the Phase I site. As some data points for this period are considerably higher than others, they are currently under review. In comparison, CO levels have been observed to exceed 1 ppm on occasion in Saint John, Fredericton and Moncton based on data from 2010.

4.4 Sulphur dioxide and total reduced sulphur

Average hourly SO₂ levels (see Figure B4 in Appendix B) were very low, with a mean of 0.07 ppb and a median of 0.02 ppb. These very low levels are due to the absence of a significant source of SO₂ emissions near the baseline site. TRS levels observed at the Phase I site were also very low, averaging 0.2 ppb, with a maximum value of 1.9 ppb (see Figure B5 in Appendix B). The annual SO₂ average for air monitoring sites in Saint John was around 1 ppb in 2010. The higher SO₂ and TRS levels observed in Saint John (at the Forest Hills site) are likely associated with an active petroleum refinery and pulp and paper industry in that area.

4.5 Nitrogen dioxide

A mean NO₂ level of 1.1 ppb and a median of 0.7 ppb are reported for the Phase I site, based on hourly average NO₂ data. These concentrations are slightly lower than levels observed at urban sites across the province. Levels were considerably below the defined 1-hour standard of 210 ppb (see Figure B6 in Appendix B). For example, the maximum NO₂ measurement at the Phase I site was 14.9 ppb.

4.6 Volatile organic compounds

Table A4 in Appendix A shows laboratory analysis results for a limited list of VOCs, based on compounds detected above the method detection limit (MDL).¹² Benzene and toluene showed the highest levels, with median concentrations of 2.9 and 1.5 $\mu\text{g}/\text{m}^3$, respectively. As a comparison, the 24-hour air quality standard for benzene is 10 $\mu\text{g}/\text{m}^3$ in the province of Quebec (MDDEFP 2013) and 2.3 $\mu\text{g}/\text{m}^3$ in Ontario (OMOE 2012). The annual mean benzene level recorded at the Forest Hills station in Saint John was 0.29 ppb in 2010 (DELG 2012), which is approximately 0.96 $\mu\text{g}/\text{m}^3$. It is expected that annual average benzene values will be lower than daily averages, as reflected in the 0.45 $\mu\text{g}/\text{m}^3$ annual average air quality standard in Ontario (OMOE 2012). Additional analyses and comparisons of VOC data will be included in future reports when the complete data set becomes available.

It should be noted that a different laboratory analysis method was adopted starting with the March 7, 2013, samples (i.e., for 6 of the 21 samples included in this report). The new method allows for the identification and measurement of additional VOCs, such as carbon tetrachloride, ethanol and pentane. This will be further discussed in subsequent reports.

4.7 Polycyclic aromatic hydrocarbons

Table A5 in Appendix A shows PAH data collected at the Phase I site. Naphthalene, phenanthrene and fluorene showed the highest median concentrations, at 5.2, 4.1 and 1.8 ng/m^3 , respectively. A maximum value of 20.1 ng/m^3 was recorded for naphthalene. As a comparison, the 24-hour air quality standard for naphthalene in the province of Ontario is 22.5 $\mu\text{g}/\text{m}^3$ (OMOE 2012).

Additional analyses and comparisons of PAH data will be included in future reports when the complete data set becomes available.

4.8 Meteorological data

The wind rose analysis in Appendix C indicates that winds were blowing predominantly from the northwest. No significant source of emissions was identified upwind of the Phase I site based on knowledge of the area and satellite photography (e.g., Google Earth; see Figure 7). Wind speeds averaged approximately 3.5 m/s (13 km/h) and rarely exceeded 11 m/s (40 km/h). Less than 1% of wind data were characterized as calm wind conditions.

¹² The MDL can be defined as the minimum concentration at which a substance can be measured and reported with 99% confidence. The MDL is determined from analysis of a sample in a given matrix containing the substance. Statistically, the 99% confidence interval means that any substance detected at a concentration equal to the MDL is 99% likely to be present at a concentration greater than zero (1% chance of false positive or Type I decision error). The MDL is a statistical rather than a chemical concept – that is, a substance can be detected at concentrations well below the MDL. The MDL differs from the instrument detection limit.



Figure 7. Wind rose indicates the frequency and directions of winds at the Phase I site between October 2012 and April 2013

Note: This image was generated using Lakes Environmental WRPLOT View Freeware 7.0.0 and Google Earth.

Temperature data are plotted in Figure C1 (see Appendix C). The average temperature for the period covered by this report was -0.07°C . In comparison, a daily average temperature of approximately -1.0°C was recorded at Moncton International Airport.¹³

4.9 Data collection issues

Some minor equipment malfunctions caused a series of invalid data collection periods; overall, however, more than 90% of the data collected were considered valid (see Table A1 in Appendix A). Only one malfunction event was noted during the first months of monitoring at the Phase I site. TSP data suffered from an important equipment breakdown on February 8, 2013, when water intrusion through the inlet head damaged electronic components. The TSP monitor was repaired and re-deployed on March 7, 2013, resulting in approximately 1 month of missing data. It is estimated that only 50% of TSP data from Phase I are valid for the period between November 2012 and April 2013.

Handling procedures for the Health Canada passive VOC samplers were modified as of April 24, 2013. Prior to this date, the technician removed a protective casing covering the diffuser membrane on the samplers. This operation has since ceased, as per the sampler handling guidelines. The impacts of this change in sampling method on VOC measurements will be assessed when the complete data set becomes available. Additional analyses and comparisons of VOC data will be included in future reports.

¹³ Based on queries at www.climate.weather.gc.ca/index_e.html#access for the period between October 2012 and April 2013.

Technical issues were also encountered with the continuous methane monitor. Insufficient testing and limited data availability do not allow for a discussion on continuous methane levels at the baseline site.

5. Next steps

5.1 Phase I

Air monitoring and sampling at the Phase I site ended in October 2013 following 52 weeks of data collection.

During the second half of this phase, continuous ambient methane measurements were collected with a Thermo Scientific Model 5500. This stationary device was acquired by the DELG and was added to the mobile unit. This device will also be used during Phase II of this study.

Data analysis will continue after QA/QC and data validation procedures have been conducted on the complete Phase I data set (see Appendix F for QA/QC procedures).

5.2 Phase II

Initiation and completion of Phase II are dependent on industrial interest and oil and gas activity in the province. Initially planned for July 2013, this phase is postponed until further notice.

In addition to monitors and samplers used to measure pollutants during Phase I, continuous real-time monitoring of organics (C2 to C12), including benzene, toluene, ethylbenzene and xylenes (BTEX), is also planned for Phase II. Samples will be measured using a gas chromatograph coupled to a flame ionization detector (GC/FID), provided by Environment Canada.

5.3 Phase III

Monitoring at the Phase III site (gas plant) was initiated on June 7, 2013, and ended on August 27, 2013.

QA/QC procedures will be conducted on the continuous data that were collected by the Airpointer unit. Data QA/QC procedures will also be applied to the sample-based data. Data analysis will begin when all laboratory results from the sample analyses are available.

5.4 Phase IV

Monitoring at the Phase IV site (inactive well site) was initiated on April 23, 2013, and ended on June 6, 2013. Data analysis will begin when all laboratory results from the sample analyses are verified according to the QA/QC protocols.

6. Concluding remarks

This interim report covers the first 6 months of activity for the New Brunswick Shale Gas Air Monitoring Study. The data available were mainly limited to continuous data collected at the

baseline site located in Apohaqui. Preliminary analyses of these data and comparisons with historical air quality trends across the southern part of the province of New Brunswick (including Fredericton, Saint John and Moncton) show that the concentrations of air pollutants at the baseline site are similar to or lower than those at other provincial monitoring sites (rural and/or urban). The wind data also indicated that no significant sources of pollution, especially oil and gas activities, were located upwind of the site. As such, it would appear that the baseline data will provide an appropriate data set against which to compare air quality data collected during other phases of the study.

As continuous and discrete data from Phases I, III and IV become available, and once appropriate data QA/QC procedures have been conducted, Health Canada will produce a second interim report.

As for Phase II of the current shale gas air monitoring study, covering the well development stage, it will be initiated as soon as a favourable project is identified by the DELG.

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Appendix A: Tables

Table A1. Descriptive statistics for continuous data collected from October 1, 2012, to April 16, 2013, at the Phase I baseline site

	CO	SO ₂	NO	NO ₂	NO _x	TRS	PM _{2.5}	TSP	O ₃
Air quality standard (AQS)	13/30 ppm	169.5 ppb		210 ppb		11 ppb (H ₂ S)	25 µg/m ³	120 µg/m ³	65 ppb (82 ppb)
AQS avg period	1 h avg	1 h avg		1 h avg		1 h avg	24 h avg	24 h avg	Max 8 h avg (1 h avg)
Reference	NAAQO	NBAAQO		NBAAQO		NBAAQO	WHO	NBAAQO	CWS (NAAQO)
Sampling frequency	5 min avg	5 min avg	5 min avg	5 min avg	5 min avg	5 min avg	1 h avg	1 h avg	5 min avg
Avg period for stats	1 h avg	1 h avg	1 h avg	1 h avg	1 h avg	1 h avg	24 h avg	24 h avg	Max 8 h avg (1 h avg)
Mean	0.212	0.067	0.332	1.12	1.436	0.199	4.72	9.71	36.2 (29.3)
Median	0.206	0.021	0.152	0.686	0.864	0.206	4.17	8.19	36.8 (31.3)
Minimum / maximum	0.012 / 0.740	0 / 4.72	0 / 11.9	0.021 / 14.9	0.001 / 23.2	0 / 1.85	0.957 / 35.5	1.25 / 39.3	12.5 / 55.1 (0 / 56.9)
5th / 95th percentiles	0.132 / 0.308	0 / 0.274	0.001 / 1.24	0.232 / 3.43	0.264 / 4.49	0 / 0.359	1.96 / 8.42	3.28 / 18.6	22.6 / 48.2 (5.2 / 46.0)
98th percentile	0.329	0.449	2.39	4.89	6.75	0.427	9.63	22.7	51.3 (48.5)
No. of AQS exceedances	0	0	0	0	0	0	1	0	0 (0)
No. of sampling days	198	198	198	198	198	198	198	198	198
No. of measurements	56 736	56 736	56 736	56 736	56 736	56 736	4 728	4 728	56 736
No. of valid measurements	52 855	54 244	54 761	53 903	54 761	50 377	4 415	2 347	54 274
% valid measurements	93.2	95.6	96.5	95.0	96.5	88.8	93.4	49.6	95.7
Abbreviations: AQO, air quality objective; avg, averaging/average; CWS, Canada-wide Standard; NAAQO, National Ambient Air Quality Objective; NBAAQO, New Brunswick Ambient Air Quality Objective; ppb, parts per billion; ppm, parts per million; WHO, World Health Organization									
Notes: Values are based on the duration indicated in the Avg period for stats row; averaging periods are fixed, except for O ₃ , which is based on an 8-hour rolling average for comparison with the CWS. For CO, 13 ppm is the maximum desirable level, and 30 ppm is the maximum acceptable level. Mean, Median, Minimum/Maximum and percentile values are in the same units as the Air Quality Standard.									

Table A2. Gravimetric PM_{2.5} data from 47 mm Teflon filters used in ChemComb Speciation Cartridges (for levoglucosan analysis) collected between November 23, 2012, and April 5, 2013, at the Phase I site

Parameter	Units	Minimum	Mean	Median	Maximum
Sample volume	m ³	14.416	14.422	14.421	14.433
PM mass	µg/filter	17.350	64.157	66.937	101.338
PM concentration	µg/m ³	1.202	4.449	4.643	7.0277

Notes: Sampling flow 10 LPM; sampling duration 1440 min; 19 samples; no values below detection limit; no invalid samples/values; minimum value recorded March 5, 2013; maximum value recorded December 17, 2012

Table A3. Gravimetric PM_{2.5} data from 47 mm Teflon filters used in ChemComb Speciation Cartridges (for metals analysis) collected between February 27, 2013, and April 11, 2013, at the Phase I site

Parameter	Units	Minimum	Mean	Median	Maximum
Sample volume	m ³	14.416	14.425	14.426	14.434
PM mass	µg/filter	23.071	52.940	46.561	97.919
PM concentration	µg/m ³	1.600	3.669	3.228	6.784

Notes: Sampling flow 10 LPM; sampling duration 1440 min; eight samples; no values below detection limit; no invalid samples/values; minimum value recorded March 5, 2013; maximum value recorded March 12, 2013

Table A4. VOC data from 3M OVM passive samples collected between November 22, 2012, and April 17, 2013, at the Phase I site

VOC	Concentrations (µg/m ³) – all 21 samples				No. of valid values below MDL	No. of valid values above MDL
	Minimum	Mean	Median	Maximum		
1,2-Dichloroethane*	0.1	0.491	0.428	0.800	1	20
α-Pinene*	0.1	0.721	0.551	2.791	2	19
Benzene*	0.524	3.000	2.850	4.767	0	21
Chloroform*	0.1	0.385	0.337	0.636	1	20
Decane (C10)	0.1	0.320	0.217	2.099	9	12
Dichloromethane*	0.1	0.407	0.315	1.175	2	19
Ethylbenzene	0.1	0.255	0.270	0.447	7	14
Hexane (C6)*	0.1	0.867	0.892	1.486	1	20
Toluene*	0.413	1.524	1.470	2.510	0	21
(m+p)-Xylene	0.1	0.453	0.462	0.801	3	18

Notes: Only VOCs with several concentrations above the MDL are shown; other VOCs had concentrations mainly or all below the MDL; the MDL for all VOCs is 0.2 µg/m³; values below the MDL substituted with 0.1 µg/m³ (½ MDL). VOCs marked with an asterisk (*) have 90% (19/21 or more) valid values above the MDL. Minimum sample exposure time: 8325 minutes; Mean sample exposure time: 9988 minutes; Median sample exposure time: 10070 minutes; Maximum sample exposure time: 11630 minutes. Nine samples flagged linked to sampling duration being 12.5–25% of target duration of 10 080 min (i.e., 7 days). No blank correction applied.

Table A5. PAH data from URG Personal Pesticide samples collected between December 5, 2012, and March 18, 2013, at the Phase I site

PAH	Concentrations (ng/m ³)				No. of valid values below MDL
	Minimum	Mean	Median	Maximum	
Acenaphthylene*	0.032	0.497	0.304	1.906	2
Acenaphthene*	0.542	1.226	1.071	3.137	0
Anthracene*	0.207	0.499	0.489	1.003	0
Benzo(a)anthracene*	0.104	0.564	0.517	2.133	2
Benzo(b)fluoranthene	0.032	0.248	0.226	0.528	18
Benzo(k)fluoranthene	0.043	0.258	0.258	0.549	18
Benzo(ghi)perylene	0.020	0.104	0.077	0.320	21
Benzo(a)pyrene	0.047	0.220	0.181	0.583	17
Chlorpyrifos (Dursban)	0.004	0.172	0.139	0.480	13
Chrysene	0.080	0.476	0.416	1.872	6
Diazinon	0.034	0.371	0.155	1.285	12
Dibenzo(a,h)anthracene	0.028	0.210	0.063	1.288	18
Fluoranthene*	0.326	0.893	0.656	2.066	0
Fluorene*	0.561	2.366	1.803	7.859	0
Indeno(1,2,3-cd)pyrene	0.006	0.129	0.064	0.600	19
Naphthalene*	0.639	5.904	5.182	20.130	0
cis-Permethrin	0.016	0.101	0.074	0.489	18
trans-Permethrin	0.007	0.064	0.025	0.451	20
Phenanthrene*	1.677	4.057	4.083	6.967	0
o-Phenylphenol	0.006	0.465	0.291	1.946	6
Piperonyl butoxide	0.004	0.048	0.015	0.290	20
Propoxur (Baygon)	0.001	0.254	0.096	0.875	15
Pyrene*	0.378	0.938	0.773	1.942	0

Notes: PAHs marked with an asterisk (*) have 90% (19/21 or more) valid values above the MDL; MDL varies per PAH; several samples had values below the MDL. Sampling flow 4 LPM; sampling duration 1440 min; 23 samples; 2 invalid samples (sample volume missing; too short sampling time). No blank correction applied.

Appendix B: Time series plots

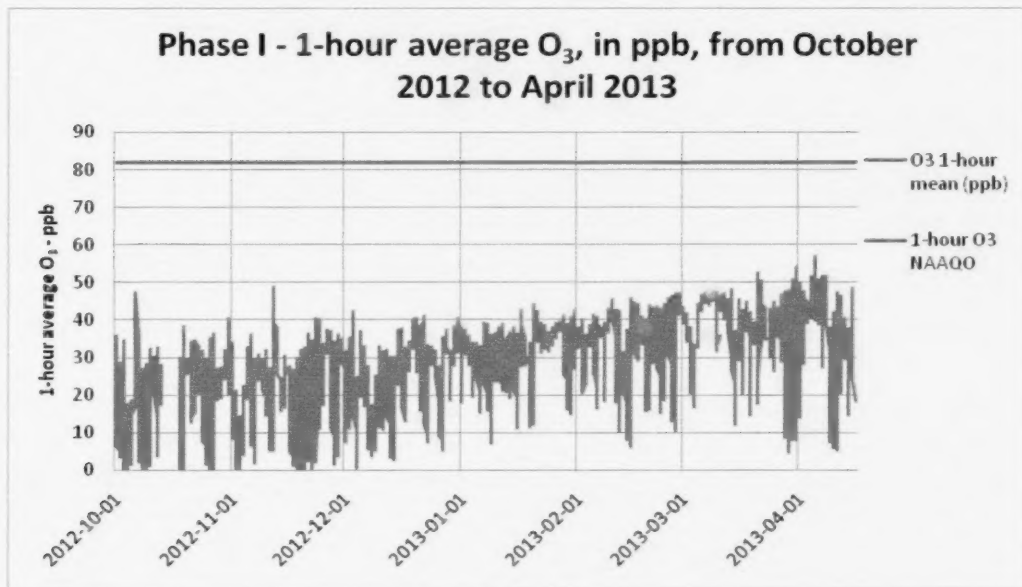


Figure B1. One-hour average O_3 concentrations observed at the Phase I site from October 2012 to April 2013

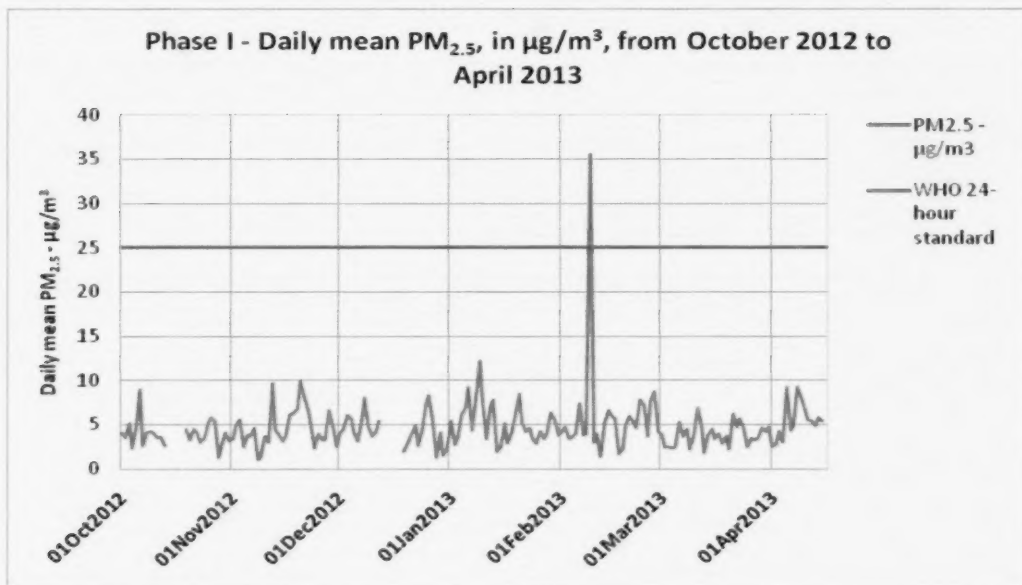


Figure B2. Daily mean fine particulate matter concentrations observed at the Phase I site from October 2012 to April 2013

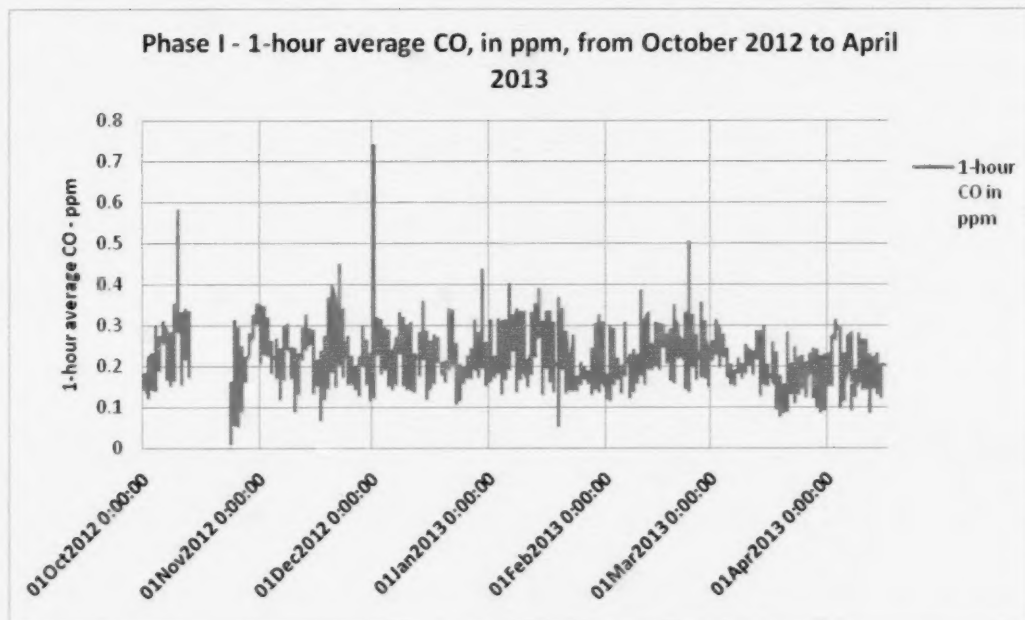


Figure B3. One-hour average CO concentrations observed at the Phase I site from October 2012 to April 2013

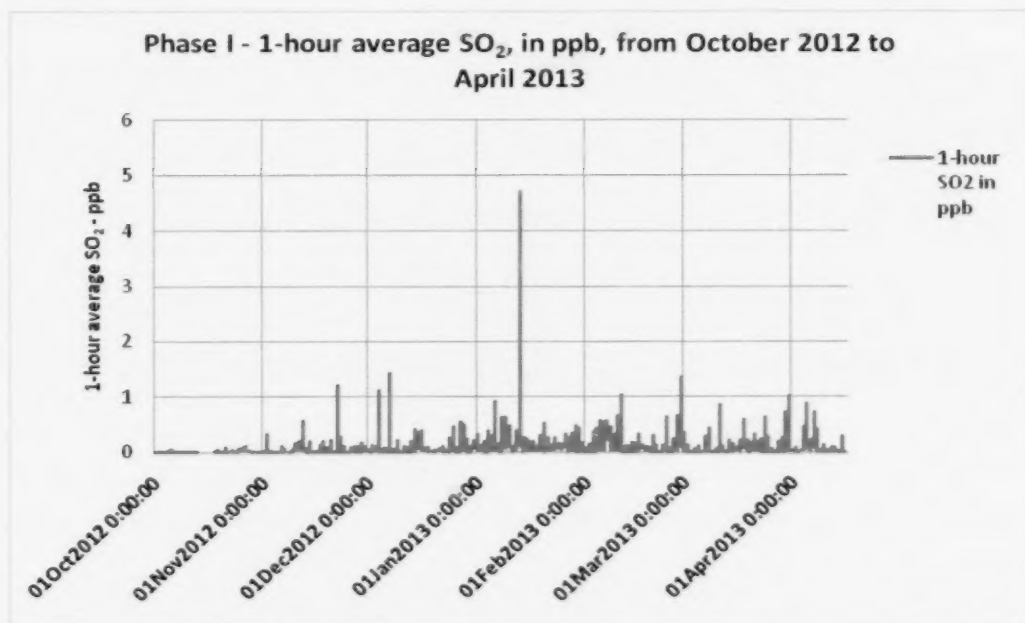


Figure B4. One-hour average SO₂ concentrations observed at the Phase I site from October 2012 to April 2013

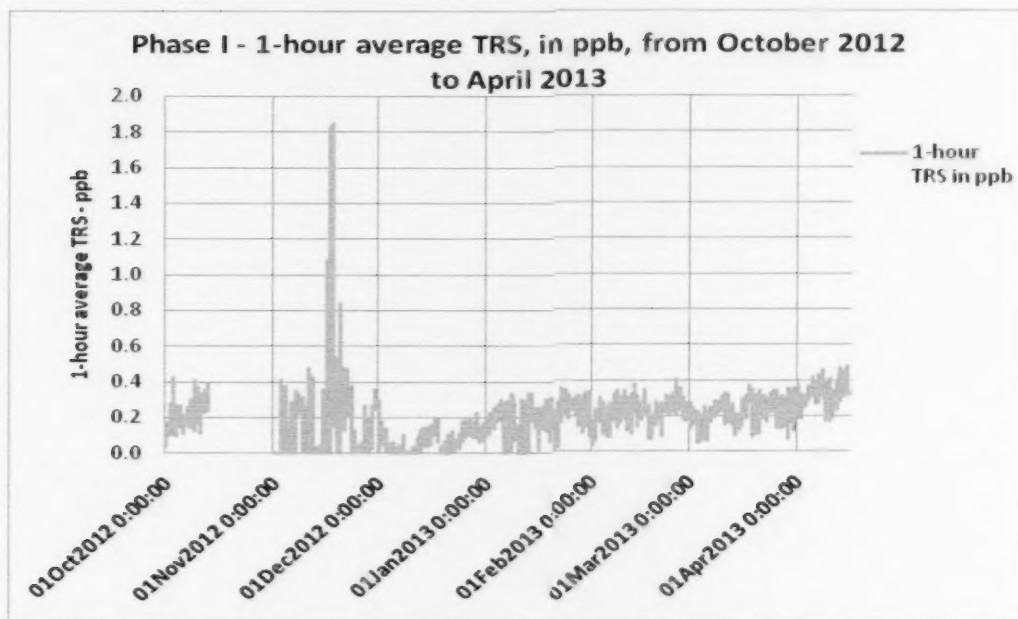


Figure B5. One-hour average TRS concentrations observed at the Phase I site from October 2012 to April 2013

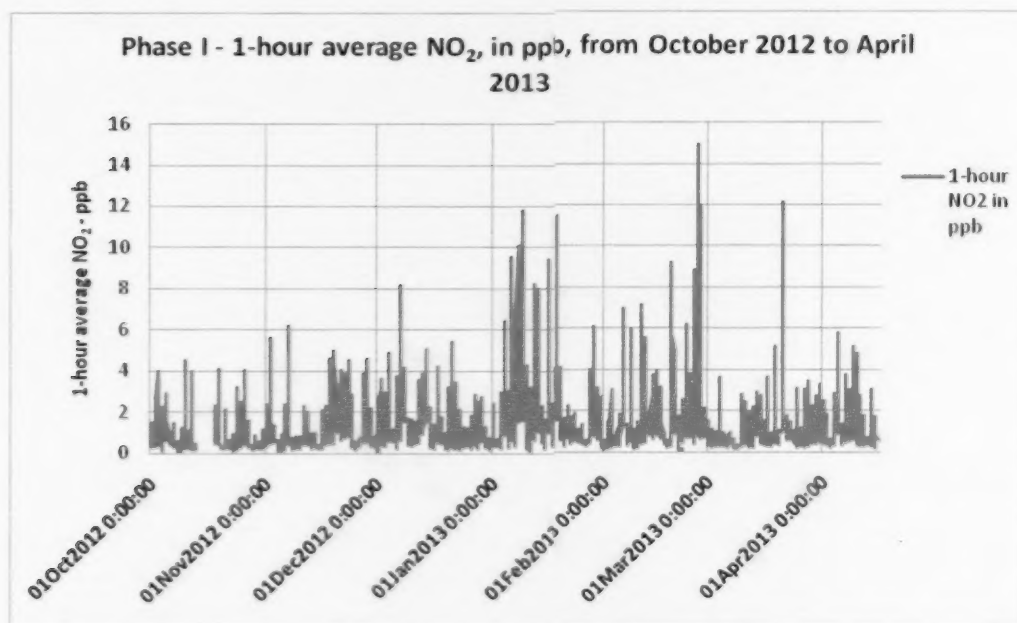
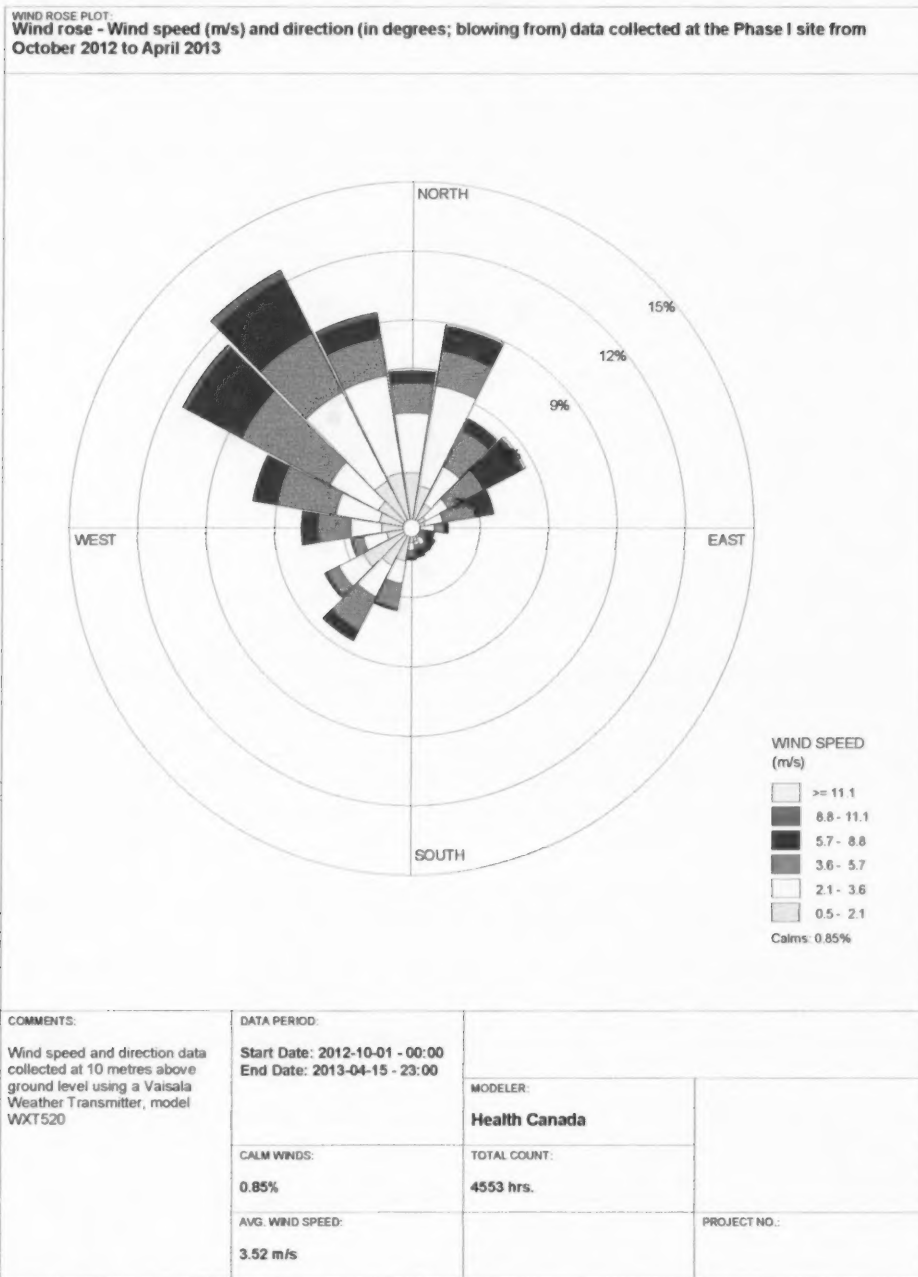


Figure B6. One-hour average NO₂ concentrations observed at the Phase I site from October 2012 to April 2013

Appendix C: Phase I meteorological data



Note: 96.2% of the wind data collected during Phase I between October 2012 and April 2013 were valid.

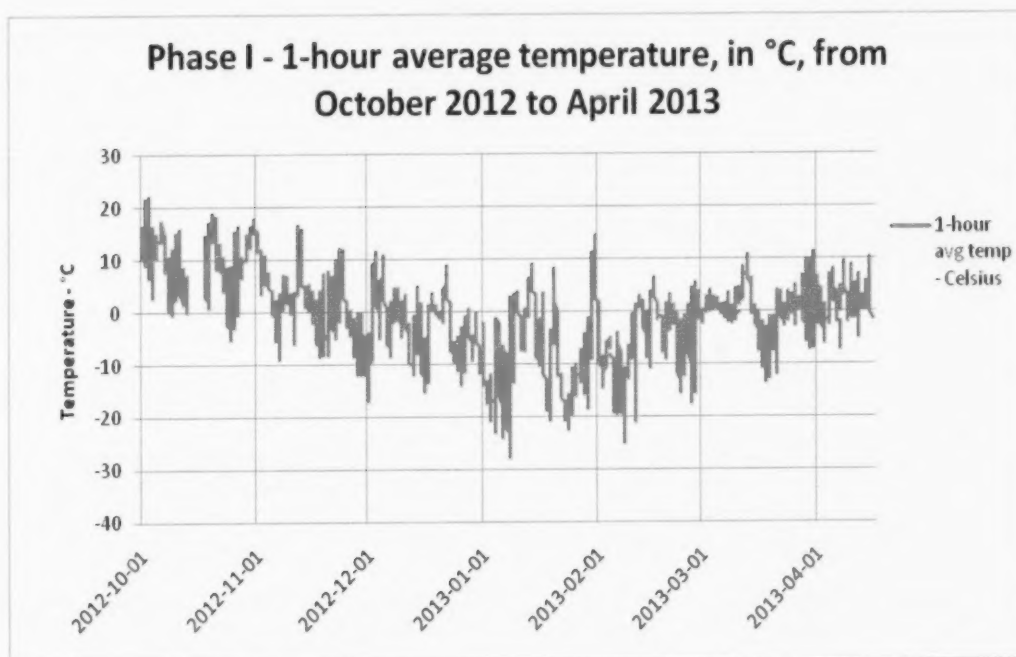


Figure C1. One-hour average temperature values observed at the Phase I site from October 2012 to April 2013

Appendix D: Monitoring equipment and laboratory analysis

Table D1. Active sampling monitors at the Phase I site from October 1, 2012, to April 16, 2013

Parameter	Instrument make and model	Calibration date	Notes
Wind speed	Vaisala WXT 520	Aug 2012	Measurements at 10 m above ground
Wind direction	Vaisala WXT 520	Aug 2012	Measurements at 10 m above ground
SO ₂	Thermo 43i	Aug 2012; Feb 2013	Continuous measurements; data files contain 5-minute averages
TRS	Thermo 43C	Aug 2012; Feb 2013	Continuous measurements; data files contain 5-minute averages
CO	Thermo 48C	Aug 2012; Feb 2013	Continuous measurements; data files contain 5-minute averages
NO ₂ /NO _x	Thermo 42C	Aug 2012; Feb 2013	Continuous measurements; data files contain 5-minute averages
PM _{2.5}	MetOne BAM1020	Aug 2012	Continuous measurements; data files contain 1-hour averages
TSP	MetOne E-BAM	Nov 2012; Mar 2013	Continuous measurements; data files contain 1-hour averages. Activated on 1-11-2012. Sampler malfunctioned on 8-02-2013; re-deployed on 7-03-2013.
O ₃	Thermo 49i	Aug 2012	Continuous measurements; data files contain 5-minute averages
VOCs – Summa canister	Xontech 910A	n.a.	Canister-based sampling every 6 days; laboratory analysis by Environment Canada
SVOCs – PUF	Modified high-volume sampler and PUF	n.a.	Sampling every 6 days; laboratory analysis by Environment Canada
Carbonyl compounds – Summa canister	Environmental Systems 926	n.a.	Canister-based sampling every 6 days; laboratory analysis by Environment Canada
PM _{2.5} speciation - gravimetric - metals - EC/OC - levoglucosan	ChemComb sampler, flow rate of 10 LPM. Teflon (metals and levoglucosan) and pre-fired quartz fibre (EC/OC) filters	unavailable	Sampling every 6 days; Alberta Innovates (Alberta Research Council) for gravimetric and ICP-MS metals analysis; Environment Canada for carbon content using DRI Model 2001 thermal/dual-optical carbon analyzer and the IMPROVE protocol; chromatography analysis by Environment Canada for levoglucosan measurements
PAHs – particle-bound and gaseous	URG Personal Pesticide sampler; PM _{2.5} bound on glass fibre filter, gaseous on 5 cm PUF	n.a.	Sampling every 6 days; Laboratory analysis by Environment Canada and AirZone laboratories
VOCs – passive	3M OVM VOC badge	n.a.	Badges are exposed for 6–8 days; laboratory analysis by Environment Canada
<i>Abbreviations:</i> EC, elemental carbon; n.a., not applicable; OC, organic carbon; PAH, polycyclic aromatic hydrocarbon; PM _{2.5} , fine particulate matter; PUF, polyurethane foam; SVOC, semi-volatile organic compound; TRS, total reduced sulphur; TSP, total suspended particulates; VOC, volatile organic compound			

Table D2. Volatile organic compounds detectable using Summa VOC canisters and GC/MS, according to US EPA method TO-15

Acetaldehyde	cis-1,2-Dimethylcyclohexane	Methylcyclohexane
Acetone	cis-1,3-Dimethylcyclohexane	1-Methylcyclohexene
Acetonitrile	cis-1,4/trans-1,3-Dimethylcyclohexane	Methylcyclopentane
Acetylene	Dimethylcyclohexane	1-Methylcyclopentene
Acrolein (2-propenal)	trans-1,2-Dimethylcyclohexane	Methyl ethyl ketone (MEK)
Acrylonitrile (2-propenenitrile)	trans-1,4-Dimethylcyclohexane	2-Methylfuran
Benzaldehyde	2,2-Dimethylhexane	3-Methylfuran
Benzene	2,4-Dimethylhexane	2-Methylheptane
Benzyl chloride	2,5-Dimethylhexane	3-Methylheptane
β-Pinene	3,6-Dimethyloctane	4-Methylheptane
Bromodichloromethane	2,3-Dimethylpentane	2-Methylhexane
Bromoform	2,4-Dimethylpentane	3-Methylhexane
Bromomethane	2,2-Dimethylpropane	Methyl isobutyl ketone (MIBK)
Bromotrichloromethane	2,2-Dimethylpentane	2-Methylpentane
1,3-Butadiene	cis-1,3-Dichloropropene	3-Methylpentane
cis-2-Butene	trans-1,3-Dichloropropene	3-Methyl-1-pentene
Butane	Dodecane	cis-3-Methyl-2-pentene
1-Butanol	Ethane	trans-3-Methyl-2-pentene
2-Butanol	Ethanol	4-Methyl-1-pentene
2-Butenal (crotonaldehyde)	Ethylacetate	cis-4-Methyl-2-pentene
1-Butene/2-methylpropene	Ethylbenzene	trans-4-Methyl-2-pentene
trans-2-Butene	Ethylbromide	2-Methylpropanal (isobutylaldehyde)
Butylacetate	2-Ethyl-1-butene	2-Methyl-2-propenal (MAC)
Butylaldehyde (butanal)	Ethylene	Methyl vinyl ketone (MVK)
n-Butylbenzene	Ethylene oxide	Nonane
sec-Butylbenzene	2-Ethyltoluene	1-Nonene
tert-Butylbenzene	3-Ethyltoluene	Naphthalene
1-Butyne	4-Ethyltoluene	Octane
Camphene	Freon 11 (trichlorofluoromethane)	1-Octene
Carbon disulphide	Freon 113 (1,1,2-trichlorotrifluoroethane)	trans-2-Octene
Carbon tetrachloride	Freon 114 (1,2-dichlorotetrafluoroethane)	Pentanal
Chlorobenzene	Freon 12 (dichlorodifluoromethane)	Pentane
Chloroethane	Freon 22 (chlorodifluoromethane)	2-Pentanone
Chloroform	Heptane	1-Pentene
Chloromethane	2-Heptanone	cis-2-Pentene
Cyclohexane	1-Heptene	trans-2-Pentene
Cyclohexanone	cis-2-Heptene	α-Pinene
Cyclohexene	cis-3-Heptene	Propane
Cyclopentane	trans-2-Heptene	Propene
Cyclopentanone	Hexachlorobutadiene	Propionaldehyde
Cyclopentene	Hexanal	Propyl alcohol (1-propanol)
p-Cymene (1-methyl-4-isopropylbenzene)		n-Propylbenzene
Dibromochloromethane		

Dibromomethane	Hexane	Propylene oxide
Decane	2-Hexanone	Propyne
1-Decene	1-Hexene/2-methyl-1-pentene	Styrene
Dichloromethane	cis-2-Hexene	1,1,2,2-Tetrachloroethane
1,2-Dibromoethane (ethylene dibromide)	trans-2-Hexene	Tetrachloroethene
1,2-Dichlorobenzene	trans-3-Heptene	Toluene
1,3-Dichlorobenzene	Hexylbenzene	1,2,4-Trichlorobenzene
1,4-Dichlorobenzene	Indan (2,3-dihydroindene)	1,1,1-Trichloroethane
1,4-Dichlorobutane	Isobutane (2-methylpropane)	1,1,2-Trichloroethane
1,1-Dichloroethane	Isobutylacetate	Trichloroethene
1,2-Dichloroethane	Isobutylalcohol	1,2,3-Trimethylbenzene
1,1-Dichloroethene	Isobutylbenzene	1,2,4-Trimethylbenzene
cis-1,2-Dichloroethene	Isoprene (2-methyl-1,3-butadiene)	1,3,5-Trimethylbenzene
trans-1,2-Dichloroethene	Isopropyl alcohol	2,2,3-Trimethylbutane
1,2-Dichloropropane	Isopropylacetate	2,2,5-Trimethylhexane
1,2-Diethylbenzene	Isopropylbenzene	2,2,4-Trimethylpentane
1,3-Diethylbenzene	Limonene	2,3,4-Trimethylpentane
1,4-Diethylbenzene	Methanol	Undecane
2,2-Dimethylbutane	Methyl acetate	1-Undecene
2,3-Dimethylbutane	2-Methylbutanal (isovaleraldehyde)	Vinyl chloride (chloroethene)
	2-Methylbutane	m-, p-Xylene
	3-Methyl-1-butanol	(m+p)-Xylene
	2-Methyl-1-butene	o-Xylene
	2-Methyl-2-butene	
	3-Methyl-1-butene	
	Methyl-tert-butyl ether (MTBE)	

Table D3. Volatile organic compounds detectable using 3M OVM passive sampling badges

Benzene	Hexachloroethane	1,1,2,2-Tetrachloroethane
Chloroform	Hexane	Tetrachloroethene
p-Cymene (1-methyl-4-isopropylbenzene)	Isopropylbenzene	Toluene
Decane	Limonene	1,2,4-Trichlorobenzene
1,3-Dichlorobenzene	Naphthalene	Trichloroethene
1,4-Dichlorobenzene	Pentachloroethane	1,2,4-Trimethylbenzene
1,2-Dichloroethane	α -Pinene	1,3,5-Trimethylbenzene
Dichloromethane	Styrene	(m+p)-Xylene
Ethylbenzene		o-Xylene

Table D4. Detectable PAHs based on selected sampling and laboratory analysis methods

Acenaphthylene	Chlorpyrifos (Dursban)	<i>cis</i> -Permethrin
Acenaphthene	Chrysene	<i>trans</i> -Permethrin
Anthracene	Diazinon	Phenanthrene
Benz(a)anthracene	Dibenzo(a,h)anthracene	<i>o</i> -Phenylphenol
Benzo(a)pyrene	Fluoranthene	Piperonyl butoxide
Benzo(b)fluoranthene	Fluorene	Propoxur (Baygon)
Benzo(ghi)perylene	Indeno(1,2,3-cd)pyrene	Pyrene
Benzo(k)fluoranthene	Naphthalene	

Table D5. ICP-MS metals analysis based on fine particulate matter sampling

Ag	Ba	Cd	Cu	Li	Na	S	Sn	Tl
Al	Be	Cl	Fe	Mg	Ni	Sb	Sr	U
As	Bi	Co	Hg	Mn	P	Se	Th	V
B	Ca	Cr	K	Mo	Pb	Si	Ti	Zn

Appendix E: 2010 New Brunswick air monitoring data

This appendix shows air monitoring data collected from sites across the southern part of the province of New Brunswick, including Saint John, Fredericton, Moncton, Norton and Fundy National Park. All data, figures and comparisons to standards are from the 2012 publication, *New Brunswick air quality monitoring results 2010* (NB DELG 2012). Health Canada did not conduct an analysis of 2010 monitoring data for the current report. The information herein provides an indication of measured air pollutant levels in southern New Brunswick. Throughout Appendix E, air monitoring values are compared to the New Brunswick Ambient Air Quality Objectives (NBAAQOs), as shown in Appendix G, unless otherwise specified.

E.1 Saint John

For the Saint John area, results are presented for Forest Hills, an urban site located east of the city, except for CO, which is monitored at one site (Customs Building) representative of the Saint John centre. Peak hourly CO values throughout the year seldom exceeded 1.0 ppm, and no exceedances of the 8-hour objective of 13 ppm were observed.

There were no exceedances of the 1-hour NO₂ objective (210 ppb), the 24-hour objective (105 ppb) or the annual objective (52 ppb) at any site during 2010.

There were no exceedances of the 1-hour National Ambient Air Quality Objective (NAAQO) for O₃ of 82 ppb. The annual average at Forest Hills was 27.5 ppb, and the 4th highest value was 50.1 ppb. The maximum 8-hour average never exceeded 65 ppb in 2010.

At sites that are part of the provincial monitoring network, PM_{2.5} was measured using Beta Attenuation Mass (BAM) monitoring technology. The annual average value for PM_{2.5} at Forest Hills was 7.3 µg/m³. The results also show that there were 5 days when the daily average PM_{2.5} levels reached above 30 µg/m³.

No exceedances of provincial TRS objectives were noted in the Saint John area.

Data for CO, NO₂, O₃, PM_{2.5}, SO₂ and TRS from provincial monitors in Saint John in 2010 are shown in Figure E1.

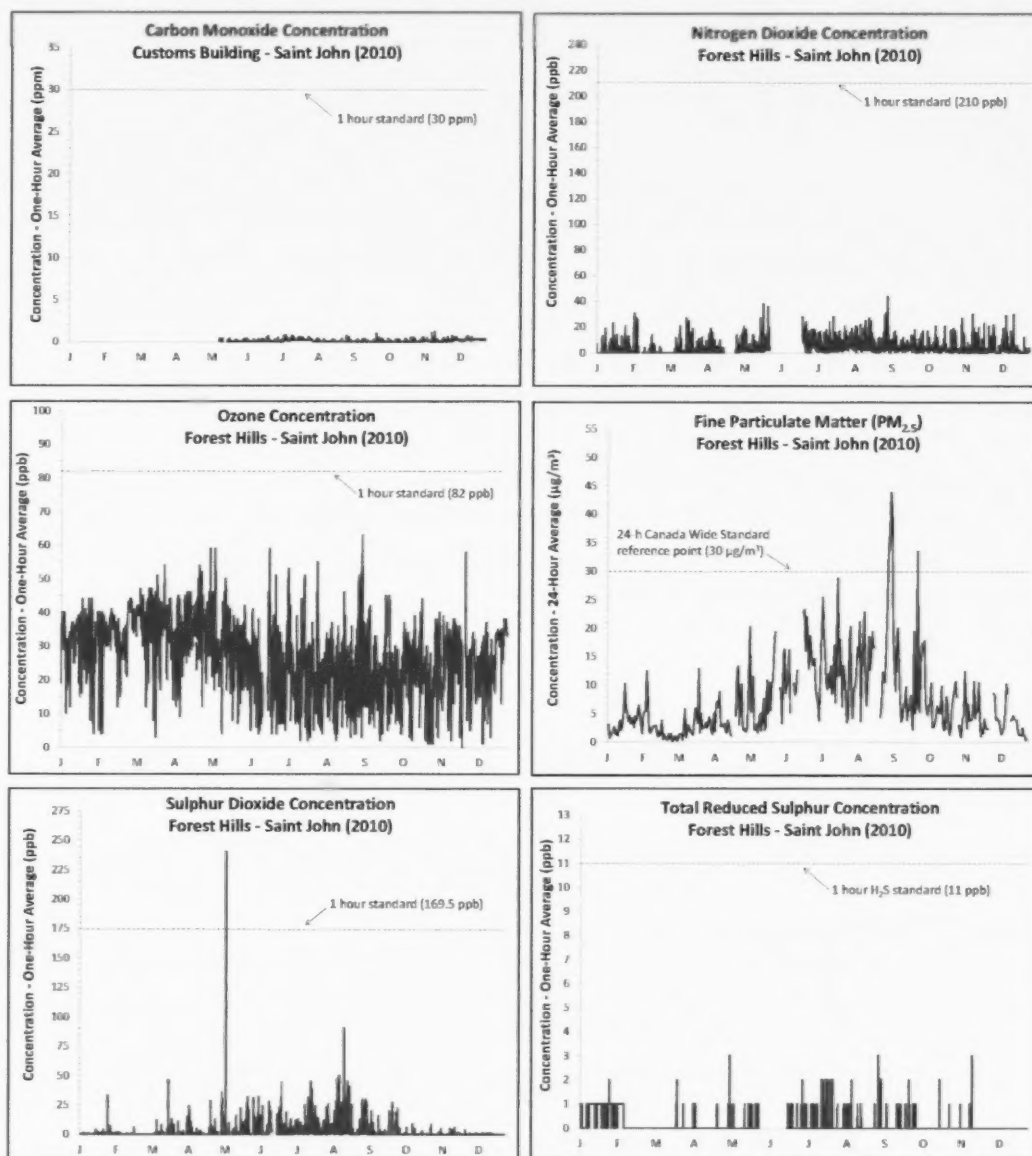


Figure E1. CO, NO₂, O₃, PM_{2.5}, SO₂ and TRS time series plots, based on data collected in 2010 from provincial monitors in Saint John

E.2 Fredericton

The Fredericton site is on Aberdeen Street, which is representative of the downtown residential and business district and also representative of a wider geographical area for some pollutants, such as O₃.

No exceedances of the 1-hour or 8-hour CO objectives (30 ppm and 13 ppm, respectively), the 1-hour or 24-hour NO₂ objectives (210 ppb and 105 ppb, respectively) or the national 1-hour objective for O₃ (82 ppb) were recorded during 2010.

Data obtained during 2010 indicated relatively low particulate concentrations. At no point did the daily average $PM_{2.5}$ levels reach above the CWS of $30 \mu\text{g}/\text{m}^3$. CO , NO_2 , O_3 and $PM_{2.5}$ measurements for 2010 are presented in Figure E2.

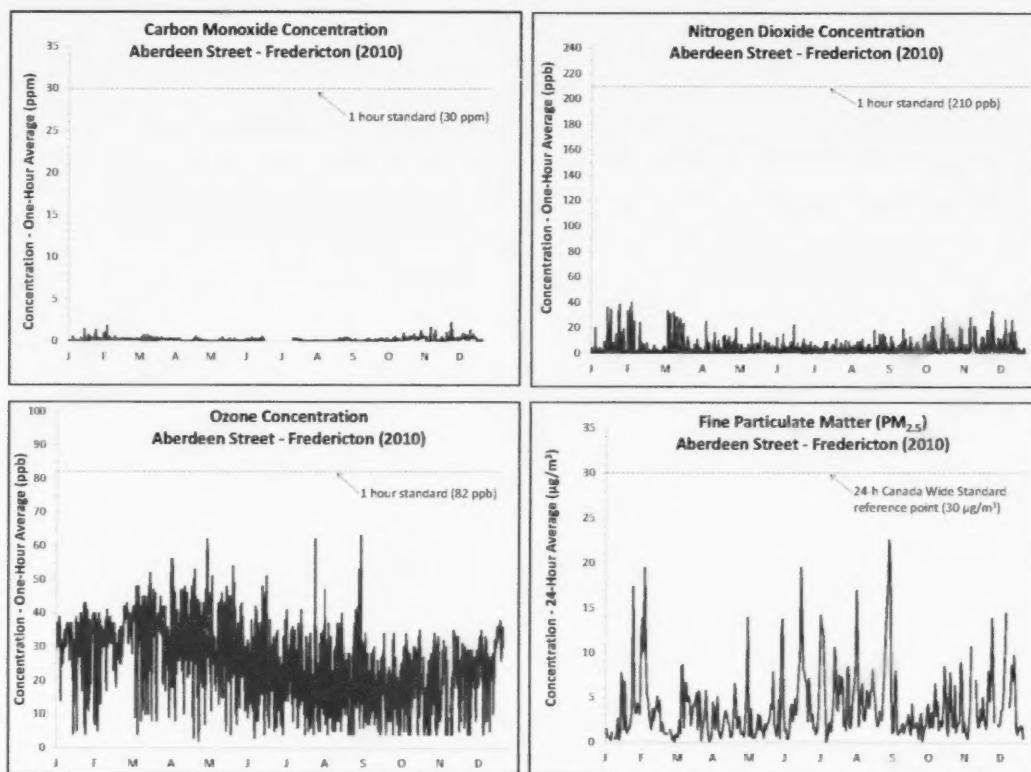


Figure E2. CO , NO_2 , O_3 and $PM_{2.5}$ time series plots, based on data collected in 2010 from a provincial monitoring site in Fredericton

E.3 Moncton

The Moncton air quality monitoring site, located at the Highfield Street water pumping station, is representative of the central city. This site is influenced by emissions from vehicles and institutional heating systems, as well as regional pollutants such as O_3 .

Readings in 2010 remained well below air quality objectives, with no exceedances of hourly or 8-hourly objectives for CO (30 ppm and 13 ppm, respectively), no exceedances of hourly or 24-hour standards for NO_2 (210 ppb and 105 ppb, respectively) and no exceedance of the hourly objective for O_3 (82 ppb).

Levels of $PM_{2.5}$ during 2010 were relatively low and never reached above the CWS reference point of $30 \mu\text{g}/\text{m}^3$. CO , NO_2 , O_3 and $PM_{2.5}$ measurements for 2010 in Moncton are presented in Figure E3.

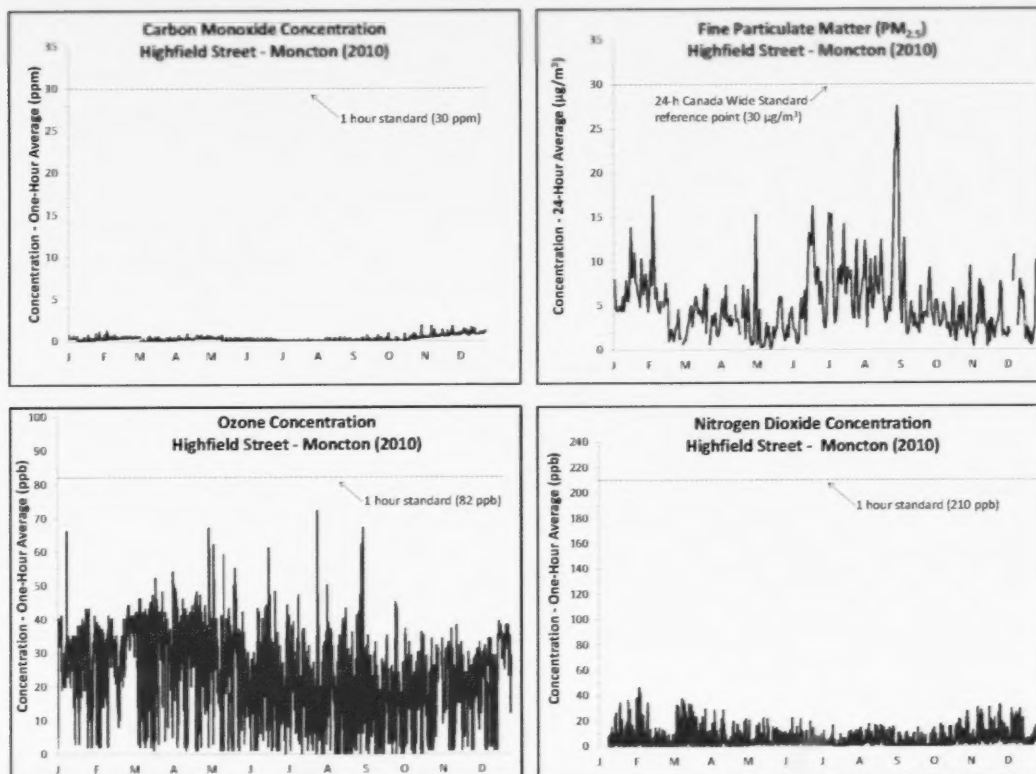


Figure E3. CO, NO₂, O₃ and PM_{2.5} time series plots, based on data collected in 2010 from a provincial monitoring site in Moncton

E.4 Fundy National Park and Norton

There was one exceedance detected in New Brunswick's rural O₃ monitoring network in 2010, occurring on May 2, 2010. The 1-hour objective of 82 ppb was exceeded for a 2-hour period at the Fundy National Park monitoring site (Figure E4). Data from the Norton monitoring station show a similar trend, but no exceedances occurred at that station.

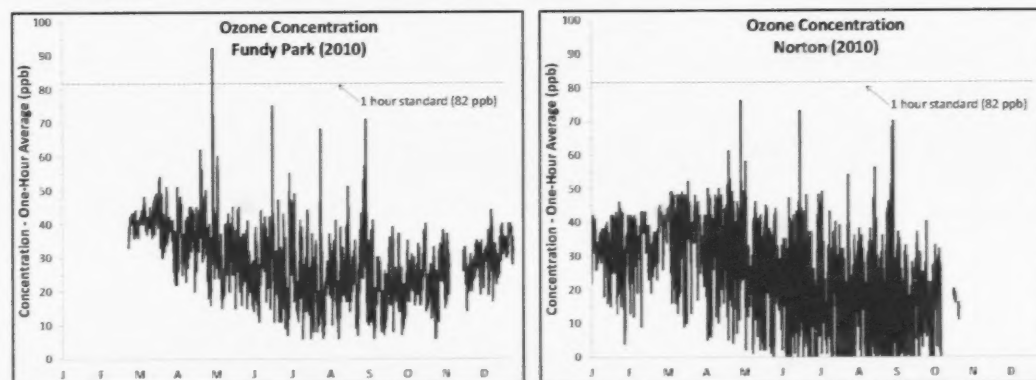


Figure E4. One-hour average O₃ time series plots, based on data collected in 2010 from provincial monitors in Fundy National Park and Norton

E.5 Annual trends

The annual trends (Figure E5) are based on a limited number of monitoring sites across the major cities in the southern part of the province (i.e., Fredericton, Saint John and Moncton).

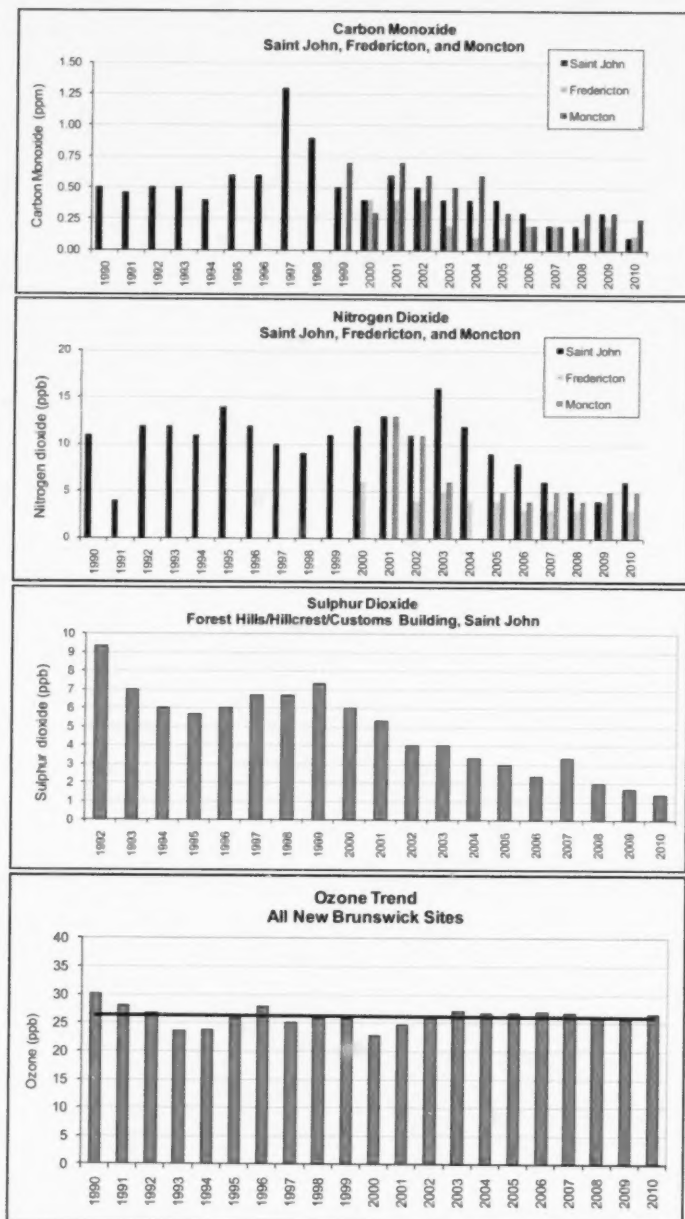


Figure E5. Annual trends in atmospheric CO, NO₂, SO₂ and O₃, based on data collected at select monitoring sites in New Brunswick

CO is monitored in the three main cities, which are the only three CO monitoring sites in the province. For NO₂, the single sites in Moncton and Fredericton were used, and one (Customs Building) of multiple sites in Saint John was selected. The averages of three sites in the Saint John

region make up the SO₂ annual trend graph, whereas O₃ data from 14 sites across the province are combined to generate an annual average.

For CO, NO₂, SO₂ and O₃, 5-minute data are validated and used to produce hourly-averaged data. These hourly means are then averaged over the entire year to produce annual averages.

Appendix F: Data quality assurance/quality control

The objective of any quality assurance and quality control (QA/QC) procedure is to provide accurate, representative, comparable, high-quality data using consistent operational protocols and standards. QA is an integrated system of management activities to ensure that the type and quality of data collected are as needed and as expected. Planning, implementation, documentation, assessment, reporting and improvement steps are involved. QA tasks include regular site inspections, instrument response verifications, analyzer calibrations and data review. QC is any test that allows a user to assess whether a monitor is performing at the desired and expected performance level. QC, through checks and comparisons, also applies to data validation to identify data that may be invalid, suspect or in need of adjustment.

Monitoring sites for the shale gas study were operated and data were reviewed according to National Air Pollution Surveillance (NAPS) program procedures and methods (refer to Environment Canada 2004; Alberta Environment 2006; NB DELG 2012; US EPA 2013). Table F1 shows typical QA/QC elements and associated activities according to the NAPS program. These QA/QC components may be considered as minimum requirements.

The NAPS program is federally coordinated, and the management of the program involves provincial, territorial and regional agencies. The latter are responsible for the ongoing operation and maintenance of monitoring stations and instrumentation, data acquisition and validation, and reporting within their jurisdictions (Environment Canada 2004).

Table F1. NAPS program QA/QC elements and activities

QA/QC element	Activities
Plan, establish, develop and manage monitoring network programs	Measurement methodology, equipment selection, operating conditions
Site selection	Spatial scale, site classification, distribution
Sampling system	Shelter requirements, probe localization, manifold design
Station and analyzer operation	Station visits, operating procedures, maintenance
Calibration	Frequency, procedures, zero and span verifications
Calibration and reference standards	Inventory of and request to the NAPS agency for reference standards
Station performance and audits	Inter-agency verifications
Data validation and formats	Audit trail
Documentation	Site and site activity log books, QA/QC manuals, analyzer operation and maintenance manuals
Training and technical support	Qualifications

Source: Adapted from Table 5.0 in Environment Canada (2004)

Every NAPS agency has in place a QA/QC program that is supplemented by a federal QA/QC program (refer to Table F1). Some of the most relevant elements are discussed in the following subsections. More stringent specifications or more elaborate QA/QC procedures may be adopted by each agency based on specific requirements. The overall objective is to generate data that remain within $\pm 15\%$ of

true values and that are representative of the parameters being measured with regard to time, location and conditions.

F.1 Monitoring stations and measurements

As mentioned previously, the mobile monitoring unit at the Phase I study site, the Airpointer unit at Phase III and all discrete sampling are operated according to NAPS standards (refer to Section 5.1 in Environment Canada 2004). Site selection and equipment selection for the monitoring unit are integral parts of the NAPS standard. The sites were selected by the DELG based on its experience with air monitoring in New Brunswick and its knowledge of the area (geography, meteorology, economic activities, etc.). Specifically for Phase I, the air quality data collected at this site are expected to be representative of the geographic area of interest. Further, as these data constitute the comparative baseline and must be as free as possible of industrial emissions (e.g., oil and gas, mining), no significant sources of emissions are located nearby in the general upwind direction.

To properly determine background air quality, data are being collected for a large spectrum of pollutants (see Section 3.1) during Phase I. In fact, the number of different pollutants measured at the Phase I site is greater than or equal to those measured at the other sites of the study. As well, the variety of sampling methods and continuous analyzers used is also greater than at other sites. As a result, a comparison between data collected at other sites and the baseline site should be possible.

There are many recognized methods for measuring the NAPS criteria air contaminants (CACs). For NAPS-equivalent stations, the methodologies used to measure air pollutants are selected based on proven reliability and performance, ease of field operation and maintenance, and cost effectiveness. Instruments are selected based on a desired performance specification rather than a strict procedure or product (e.g., a specific make and model). Some of the key specifications for the monitors used to measure CACs, according to the NAPS requirements, are presented in Table F2.

The proper design of the sampling system in a monitoring station is essential for ensuring data quality. The temperature stability of the shelter, location of the sampling probe, manifold system design, length and composition of sample lines, and composition of filters and fittings are specifically designed to ensure the integrity of the air samples and the resulting data quality (Environment Canada 2004). Station and analyzer operation at the Phase I site was the responsibility of New Brunswick. Operation of the station included regularly scheduled station visits (weekly), instrument zero and span verifications (manual zero/span verifications during site visits for CO and methane analyzers; automated daily zero/span verifications for other instruments), calibrations (every 6 months, following repairs, if excessive span, and newly installed devices), preventive maintenance and documentation. Details regarding calibration procedures and analyzer zero and span verifications are provided in the NAPS QA/QC guidelines (Environment Canada 2004). The QA/QC program also included the calibration of flow rates, leak tests, collection of routine field blanks and determination of accuracy for the chemical analyses. Field blanks comprised approximately 10% of all samples for non-continuous instrumentation (i.e., 1 field blank sample for every 10 field

samples). Finally, monitoring and sampling instruments were operated according to procedures described in the operation manuals.

Table F2. Measurement methods and operating specifications of NAPS analyzers

Pollutant	Measurement method	Monitor type	Operating range	Operating temperature	Minimum detection limit
CO	Infrared gas filter correlation	Continuous automated	50 ppm	15–35°C	0.1 ppm
SO ₂	Ultraviolet fluorescence	Continuous automated	1.0 or 0.5 ppm	15–35°C	0.002 ppm
NO _x	Chemiluminescence	Continuous automated	1.0 or 0.5 ppm	15–35°C	0.002 ppm
O ₃	Ultraviolet absorption	Continuous automated	1.0 or 0.5 ppm	15–35°C	0.002 ppm
PM	Virtual impactors; gravimetric filter; microbalance filter; beta radiation attenuation	Continuous automated and manual gravimetric	Per operator procedures	Per operator procedures	1.0 µg/m ³
Organic compounds	Manual GC/MSD	Manual canister	–	–	–

Abbreviations: GC/MSD, gas chromatography with mass selective detector; NAPS, National Air Pollution Surveillance; NO_x, nitrogen oxides; PM, particulate matter; ppm, parts per million
Source: Adapted from Table 5.1.3 in Environment Canada (2004)

Some pollutants are measured by equivalent but different equipment at the different sites. For example, although all equipment used in this study is expected to be precise and accurate, the mobile air monitoring unit operated by the DELG is not equipped with the identical make and model equipment as the Airpointer unit provided by Health Canada. To ensure that the data collected, especially for the CACs, are consistent, the Airpointer and the mobile unit will be located near each other during Phase II. This will allow for a comparison between data from the different monitors used during this study. Comparability is a measure of the confidence with which one data set can be compared with another, which is critical to evaluating their measurement uncertainty and usefulness (US EPA 2013).

Both the mobile unit and the Airpointer use a Vaisala Weather Transmitter WXT520 unit to collect meteorological data.¹⁴ It measures barometric pressure, humidity, precipitation, temperature, and wind speed and direction. No correction procedure was applied to the weather data. The unit is certified every 2 years by the manufacturer, and it does not require regular calibration. Outlying data may be edited and marked in the data set as either unavailable or invalid. Data collected from both units during Phase II will be compared to check the consistency of the data.

F.2 Data validation

Data validation is defined as the confirmation through examination and provision of objective evidence that particular requirements for a specific intended use are fulfilled. Through validation

¹⁴ www.vaisala.com

and review techniques, data are accepted, rejected or qualified (i.e., flagged) in an objective and consistent manner (Alberta Environment 2006; US EPA 2013). According to the NAPS guidelines, the NAPS network agencies must provide sufficient QA/QC to ensure that the ambient air monitoring data collected are of acceptable precision,¹⁵ accuracy,¹⁶ completeness, comparability and representativeness. As mentioned previously, data generated from the NAPS network should be within $\pm 15\%$ of true values (Environment Canada 2004).

Data validation is a multi-step process to ensure that the data are complete and representative. Data completeness criteria exist for CACs. Although the criteria differ between pollutants and specific considerations may apply, the general principle is that 75% of the data must be complete. For example, for every valid daily average, 75% of the hours of data for that day must be valid. In addition, for each quarter of the year, 75% of the daily averages must be valid.

The data are reviewed and cleaned continuously by New Brunswick and Health Canada prior to analysis. New Brunswick follows the NAPS QA/QC protocols developed by Environment Canada for data validation. Data validation is performed using the Envista software. Another task is a review of the zero and span check data for the monitoring station at Phase I. Data that are flagged (e.g., unexplained spikes, zero or negative values) are investigated, and actions, if required, are reported. Outliers do not necessarily indicate that the data are invalid, but they can suggest the existence of a problem to the data reviewer. In general, data should not be invalidated until it can be shown that they are not valid (US EPA 2013). Some data points may be removed from further processing activities. A summary of outliers will be discussed in the final report.

Health Canada uses an equivalent in-house procedure. Common flags used to qualify continuous data are shown in Table F3. Additional flags are used in the data sets to qualify the sample status, including field and laboratory comments.¹⁷ The Health Canada QA/QC approach used for the shale gas study is the same as the one used for other studies led by the Health Canada Exposure Assessment Section. Health Canada is populating a Statistical Analysis System (SAS) database with continuous and discrete monitoring data from Phase I (baseline site), which includes results from both organizations. Similar databases will be created for other phases of the study when the data become available.

Additional validation procedures (referred to as Level II data validation) are performed soon after a scheduled calibration and also following automated and manual zero or span verifications, so that the data being reviewed are bracketed by calibrations. During this stage, flagged values are investigated and validated or invalidated. For example, designated negative values are reset to zero.

¹⁵ Precision: degree to which repeated measurements show the same results; reproducibility or repeatability.

¹⁶ Accuracy: degree of closeness of quantitative measurements to that of the quantity's actual or true value.

¹⁷ As per the procedures indicated in the Health Canada internal document *Air pollution exposure data: compilation guideline*, produced and updated by the Exposure Assessment Section (not authorized for distribution).

Monitoring records regarding procedures, conditions and events during data collection and all QA records must be available to perform Level II data validation.

Table F3. Data flags assigned during validation procedures of continuous data, as used in the Health Canada database

Flag	Description
0	Valid, no error
1	Invalid or InVld (less than -3 for O ₃ and SO ₂ , less than -5 for NO/NO _x , less than -0.5 for CO)
3	No data; data logger did not collect data for a parameter for a period of time (e.g., power outage, analyzer breakdown, data logger breakdown)
4	Data correction to 0 (e.g., between 0 and -3 for O ₃ , SO ₂ and PM; between 0 and -5 for NO/NO _x ; between 0 and -0.5 for CO)
5	Calm (wind)
6	Span
8	Calibration
10	Zero drift correction applied
22	Zero

Some samples required the use of pumps with specific flow rates. Flow rates were tested at the beginning and end of each sampling period. If the end flow rate deviated from the target flow value by 10% or more, the sample was considered invalid. Samples were also deemed invalid if they were deployed for more or less than 10% of the scheduled time.

F.3 Sample custody and laboratory analysis

Samples collected during every phase of the shale gas study are clearly identified with unique labels. Information regarding the location, time and conditions of the sampling are manually recorded on specific log sheets. These records are stored and remain available. Electronic copies of the log sheets are also generated on a regular basis. The chain of custody is recorded on a distinct form, documenting who is in charge of the sample and when samples are passed on, from the field technician up to the laboratory technician. These forms accompany all samples that are shipped and are filed appropriately.

The laboratory analyses for the samples collected by Health Canada and the DELG were conducted by federal (Environment Canada) and private laboratories (RPC laboratories, AirZone and Alberta Innovates). All laboratories follow good laboratory practice (GLP) and standard operating procedures (SOPs). GLP refers to general practices that relate to most measurements made in a laboratory. They are usually independent of the SOPs and cover subjects such as maintenance of facilities, records, sample management and handling, reagent control and cleaning of laboratory glassware. For consistency in laboratory technique, these activities are generally documented (US EPA 2013).

For ambient air samples to provide useful information or evidence, laboratory analyses must meet the following four basic requirements (US EPA 2013):

- Equipment must be frequently and properly calibrated and maintained;
- Personnel must be qualified;
- Analytical procedures must be in accordance with accepted practice, be properly documented and have received peer and management review; and
- Complete and accurate records must be kept.

Environment Canada laboratories adhere to the highest laboratory standards and apply rigorous QA/QC procedures. RPC laboratories are accredited with the Standards Council of Canada and conform to the *General requirements for the competence of testing and calibration laboratories* (ISO/IEC 17025) for the scope of testing they conduct.¹⁸ AirZOne laboratories are accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA) for specific tests (e.g., VOCs, PAHs and TSP in air).¹⁹ AirZOne applies a strict QA program, and the methods used meet or surpass regulatory and/or industry requirements (e.g., Environment Canada, US EPA and the US National Institute for Occupational Safety and Health). Alberta Innovates is a provincially managed laboratory (Alberta Research Council) that is fully accredited by the CALA through the Standards Council of Canada.²⁰

Table F4 lists examples of acceptable methods for the analysis of air samples, as presented by the US EPA (2013). Methods and references may vary based on regulatory agencies and QC requirements for the analytical methods. As laboratory analysis data available for this interim report are limited, a discussion of laboratory detection limits and field detection limits will be included in a subsequent report.

Table F4. Accepted analytical methods for air samples (e.g., filters, cartridges, foams)

Pollutant, sample	Method	US EPA reference
PM ₁₀ – high volume	Gravimetric	40 CFR Part 50 App B
PM ₁₀ – dichotomous	Gravimetric	40 CFR Part 50 App J
PM _{2.5}	Gravimetric	40 CFR Part 50 App L
PM ₁₀	Gravimetric – difference	40 CFR Part 50 App O
VOCs	GC/MS	TO-15
Carbonyls	HPLC	TO11-A
Non-methane OCs	Cryogenic preconcentration and direct flame ionization	TO-12
Metals	ICP	IO 3.5
Aldehydes	HPLC	TO11-A
OC, EC	Thermal optical reflectance (IMPROVE method)	CSN QAPP and SOPs
Abbreviations: EC, elemental carbon; GC/MS, gas chromatography/mass spectrometry; HPLC, high-performance liquid chromatography; ICP, inductively coupled plasma; OC, organic carbon; PM _{2.5} , particulate matter ≤ 2.5 µm in diameter; PM ₁₀ , particulate matter ≤ 10 µm in diameter; VOCs, volatile organic carbons; CSN, PM _{2.5} Chemical Speciation Network; QAPP, Quality Assurance Project Plan; SOPs, Standard Operating Procedures		
Source: Adapted from US EPA (2013), Table 9-1		

¹⁸ www.rpc.ca

¹⁹ www.airzoneone.com/lab-analysis/; www.cala.ca/index.html

²⁰ www.albertatechfutures.ca/RDSupport/EnvironmentandCarbonManagement.aspx

Appendix G: New Brunswick air quality objectives and monitoring network and Canadian air quality objectives

G.1 Air quality objectives

New Brunswick recognizes a number of air quality objectives and standards, some of which are regulated or voluntary in nature. New Brunswick ambient air quality objectives (NBAAQOs) for CO, hydrogen sulphide (H₂S), NO₂, SO₂ and total suspended particulates (TSP) are included in Table G1. These objectives are established under the province's *Clean Air Act*, which also includes a provision for required annual reporting to the province's Legislative Assembly on achievement of the objectives. No NBAAQO exists for ground-level O₃.

New Brunswick is also a signatory to the Canada-wide standards (CWS) for fine particulate matter (PM_{2.5}) and O₃. The Canadian Council of Ministers of the Environment endorsed standards for PM_{2.5} and O₃ in June 2000, which came into force for the 2010 reporting year. These standards are slightly different from AQOs, as they apply to long-term trends. The CWS for O₃ is 65 ppb, calculated as a 3-year rolling average of the 4th highest daily average in each year. The CWS for PM_{2.5} is 30 µg/m³, calculated as a 3-year rolling average of the 98th percentile (i.e., nearly the highest) daily average value in each year. The national objectives for O₃ and PM_{2.5} are the reference, although they are not legally binding.

Table G1 also includes National Ambient Air Quality Objectives (NAAQOs), which are set by the federal government based on recommendations from a National Advisory Committee and Working Group on Air Quality Objectives and Guidelines. Provincial governments have the option of adopting these either as objectives or as enforceable standards, according to their legislation. NAAQOs must be consistent with the philosophy of the *Canadian Environmental Protection Act, 1999* and must be based on recognized scientific principles that include risk assessment and risk management. The Canadian Ambient Air Quality Standards (CAAQS) under Canada's Air Quality Management System were established as objectives on May 25, 2013. Provinces and territories will implement actions to meet these new objectives as of 2015. CAAQS provide a new approach for managing O₃ and fine PM pollution via different objective levels.

The monitoring results from the current study will be compared with applicable values from Table G1 to verify if any exceedances are recorded during the different phases of the study. The values in Table G1 will also provide some perspective for the analysis of recorded levels at the different sampling sites. As the monitoring at each site is limited to a maximum of 1 year, it does not seem appropriate to compare the air monitoring data for PM_{2.5} with the PM_{2.5} CWS, which is based on long-term monitoring data (i.e., 3-year average of the 98th percentile). Further, as there are no daily limits for PM_{2.5} under the Canadian or New Brunswick objectives and standards, the World Health Organization (WHO) 24-hour average PM_{2.5} air quality standard of 25 µg/m³ will be used.

Table G1. National and New Brunswick air quality objectives

Air contaminant		Concentrations			
National Ambient Air Quality Objectives (not to be exceeded) ^a					
		Maximum desirable level		Maximum acceptable level	
SO ₂	1-hour average	450 µg/m ³	0.17 ppm	900 µg/m ³	0.34 ppm
SO ₂	24-hour average	150 µg/m ³	0.06 ppm	300 µg/m ³	0.11 ppm
SO ₂	Annual arithmetic mean	30 µg/m ³	0.01 ppm	60 µg/m ³	0.02 ppm
PM (TSP)	24-hour average			120 µg/m ³	
PM (TSP)	Annual geometric mean	60 µg/m ³		70 µg/m ³	
CO	1-hour average	15 mg/m ³	13 ppm	35 mg/m ³	30 ppm
CO	8-hour average	6 mg/m ³	5 ppm	15 mg/m ³	13 ppm
O ₃	1-hour average	100 µg/m ³	51 ppb	160 µg/m ³	82 ppb
O ₃	24-hour average	30 µg/m ³	15 ppb	50 µg/m ³	25 ppb
O ₃	Annual arithmetic mean			30 µg/m ³	15 ppb
NO ₂	Annual arithmetic mean	60 µg/m ³	0.03 ppm	100 µg/m ³	0.05 ppm
NO ₂	1-hour average			400 µg/m ³	0.21 ppm
NO ₂	24-hour average			200 µg/m ³	
Canada-wide Standards ^b					
O ₃	Maximum 8-hour average	65 ppb			
PM _{2.5}	Daily average	30 µg/m ³			
Canadian Ambient Air Quality Standards (management levels; 2015) ^b					
		Achieve	Prevent exceedance	Prevent air quality deterioration	Keep clean areas clean
O ₃	Maximum 8-hour average	63 ppb	56 ≤ 63 ppb	50 ≤ 56 ppb	≤ 50 ppb
PM _{2.5}	Daily average	28 µg/m ³	19 ≤ 28 µg/m ³	10 ≤ 19 µg/m ³	≤ 10 µg/m ³
PM _{2.5}	Annual average	10 µg/m ³	6.4 ≤ 10 µg/m ³	4.0 ≤ 6.4 µg/m ³	≤ 4.0 µg/m ³
New Brunswick Ambient Air Quality Objectives					
CO	1-hour average	30 ppm			
CO	8-hour average	13 ppm			
H ₂ S	1-hour average	11 ppb			
H ₂ S	24-hour average	3.5 ppb			
NO ₂	1-hour average	210 ppb			
NO ₂	24-hour average	105 ppb			
NO ₂	Annual average	52 ppb			
SO ₂ ^c	1-hour average	339 ppb			
SO ₂	24-hour average	113 ppb			
SO ₂	Annual average	23 ppb			
TSP	24-hour average	120 µg/m ³			
TSP	Annual average	70 µg/m ³			
^a Conditions of 25°C and 101 kPa are used as the basis for conversion from µg/m ³ to ppm (parts per million).					
^b For O ₃ , maximum 8-hour average, 3-year rolling average of the 4th highest daily average in each year; for PM _{2.5} , daily average, 3-year rolling average of the 98th percentile daily average value in each year.					
^c The standards for SO ₂ are 50% lower in Saint John, Charlotte and Kings counties.					
Sources: NB DELG (2012): http://www.ec.gc.ca/rmspa-naos/					

G.2 Air quality monitoring network

The Government of New Brunswick conducts air quality monitoring to ensure compliance with air quality objectives or regulatory standards. In collaboration with federal agencies (e.g., NAPS) and

industry partners, 56 monitoring sites are currently operational across the province, using continuous and intermittent sampling equipment to measure a variety of pollutants, including CACs and air toxics. The location of the monitoring stations is the result of local knowledge, DELG staff expertise and computer dispersion modelling. In addition, monitors have been installed near major point sources, such as electricity generating stations and pulp mills.

Some DELG sites were established especially to monitor the long-range transport of pollutants, such as smog precursor (e.g., O_3 , $PM_{2.5}$) and acid precipitation monitoring sites. For example, O_3 is measured continuously at a site in Norton, located within 35 km of most sampling sites selected for this study, and at Fundy National Park, southeast of the study area. The locations of air quality monitoring sites in New Brunswick are shown in Figure G1, identified by black dots. The yellow arrow indicates the general area of Sussex where the study sites are located.

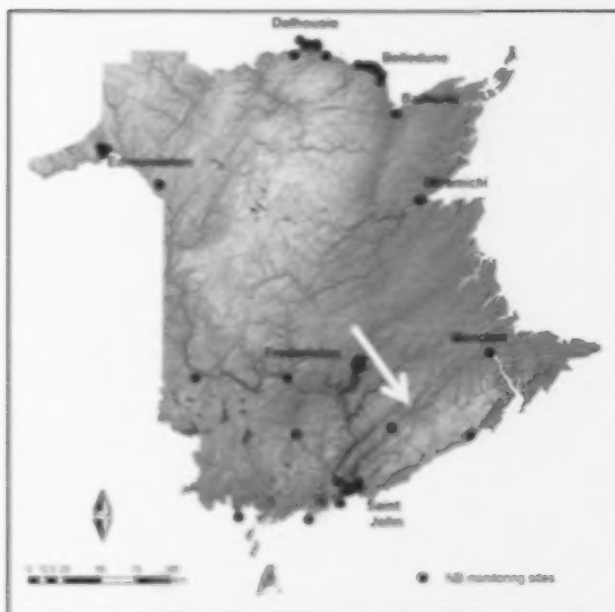


Figure G1. Locations of air monitoring sites in New Brunswick, 2010

(Source: NB DELG 2012)

Figure G2 shows the locations (indicated by stars) where ground-level O_3 is monitored in the southern portion of New Brunswick. This is the region most affected by long-range transport of pollutants from sources outside of New Brunswick, which can lead to exceedances of the 24-hour rolling average NAAQO for O_3 .

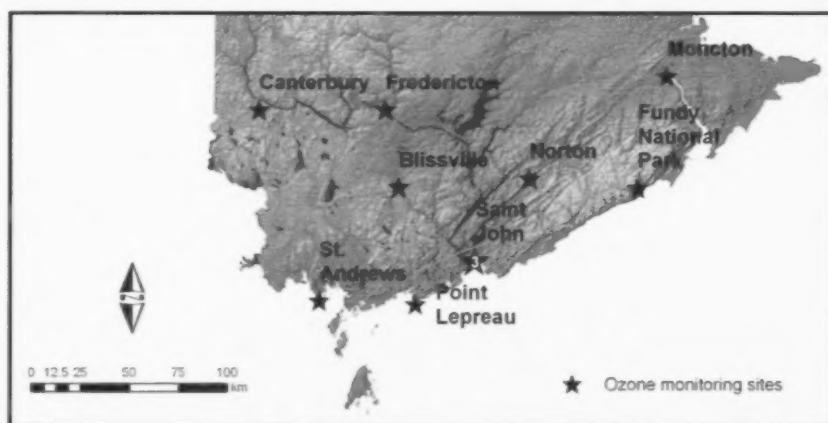


Figure G2. Locations of O₃ monitoring sites in southern New Brunswick, 2010

(Source: NB DELG 2012)

When appropriate, monitoring data from the current study will be compared with available data from the New Brunswick air quality monitoring network, such as those presented in the annual *New Brunswick air quality monitoring results* reports produced by the DELG (e.g., NB DELG 2012). Table G2 presents a summary of pollutants measured during the different study phases and data available from the provincial monitoring program. Additional meteorological data may also be obtained from the Meteorological Service of Canada.

Table G2. Summary of pollutants measured during the study phases and at various sites of the provincial air monitoring network

	TSP	PM _{2.5}	CO	EC/OC Levogl. Gravim.	NO ₂	O ₃	VOC	CC	PAH	SO ₂	TRS	Met. ^a
New Brunswick air monitoring network												
Saint John - Forest Hills		X		X	X	X	X			X	X	X
Fredericton		X	X		X	X						X
Moncton		X	X		X	X						X
Norton						X						
Fundy National Park						X						X
New Brunswick Shale Gas Air Monitoring Study												
Phase I	X	X	X	X	X	X	X	X	X	X	X	X
Phase II	X	X	X	X	X	X	X	X	X	X	X	X
Phase III		X	X		X	X	X	X	X	X	X	X
Phase IV							X					
Abbreviations: CC, carbonyl compounds; EC/OC, elemental carbon and organic carbon; Gravim.: gravimetric PM analysis; Levogl., levoglucosan; Met.: meteorology												
^a Meteorological data are being collected at the sampling location or regionally.												